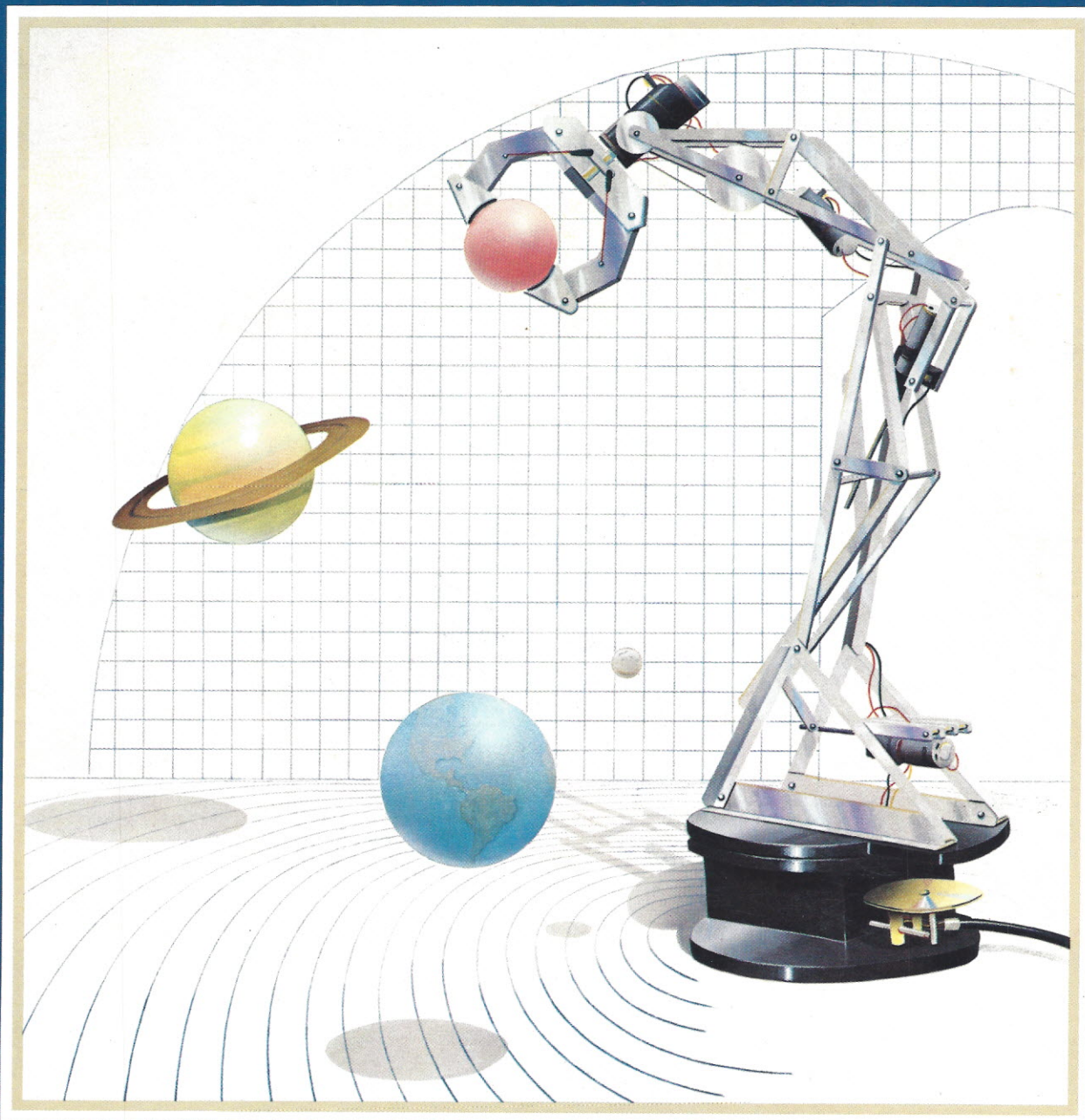


MARCH 1984 VOL. 6 NO. 3

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THE JOURNAL OF INTELLIGENT MACHINES

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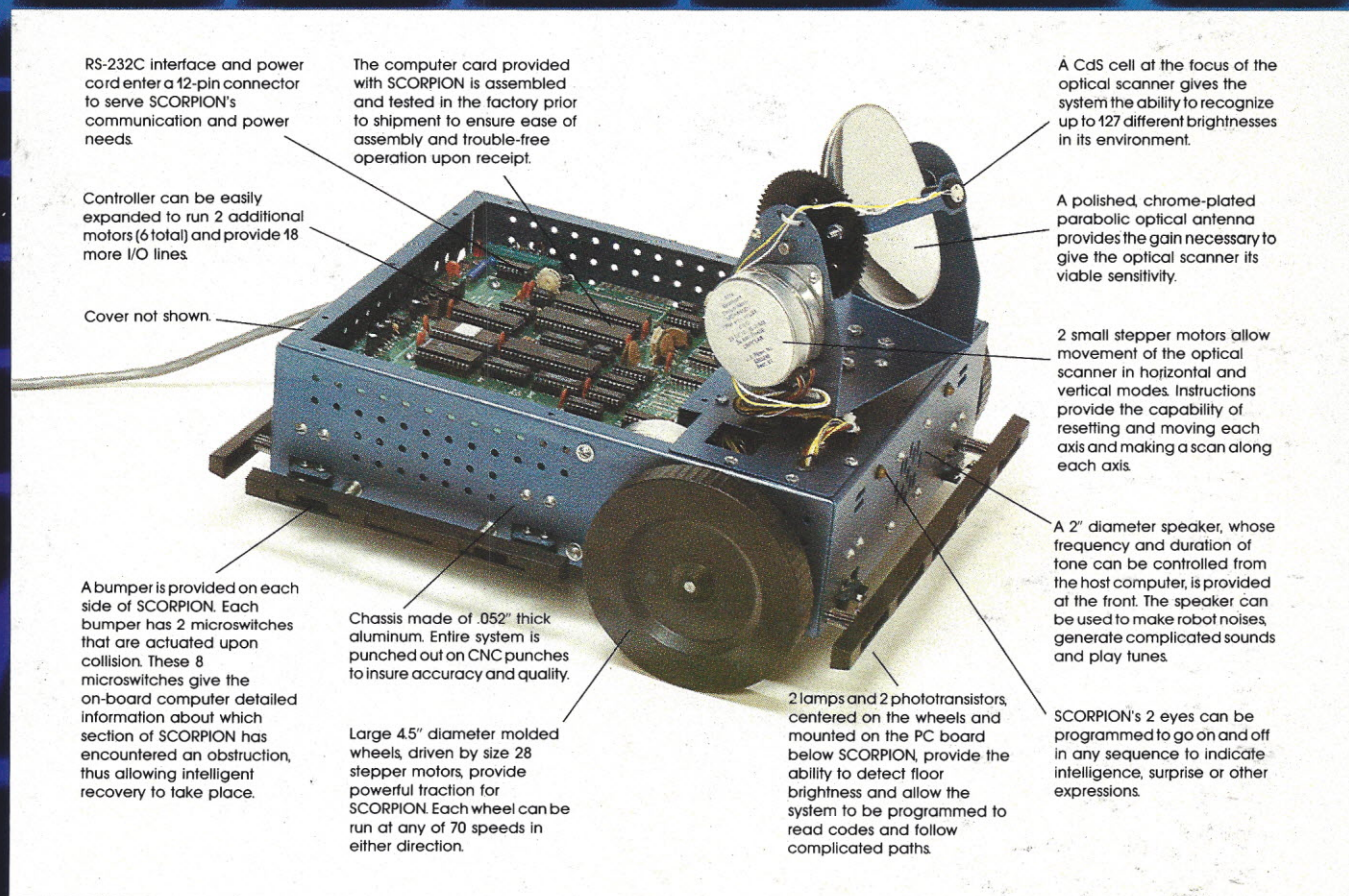
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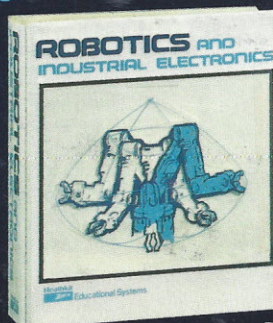
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THE JOURNAL OF INTELLIGENT MACHINES

ROBOTICS AGE™

MARCH 1984

VOL. 6 NO. 3

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About the cover: The robot arm depicted by Jonathan Graves in this fanciful cover was designed and constructed over a two-year period by D. F. Boyd. Armega 33 is constructed from standard, available parts and designed to size specifications similar to a human arm.

BPA Membership (SMA Division) Applied for, August 1983



International Personal Robot Congress

ALBUQUERQUE, NEW MEXICO April 13-15, 1984

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Editorial

Why Bother With Toys?

Toys. Do they have a serious purpose? Can we learn from them?

The January 1984 issue of *Robotics Age* contained an article titled "Super Armatron." The article described a series of modifications which the authors made to a plastic toy, the Armatron robot arm, sold by Radio Shack stores. While looking over the Reader Response cards for that issue, I noticed a commentary from one reader. He had circled the response for the Armatron article and written in the border, "Why bother with toys?"

For those readers not familiar with the Armatron, it is a \$30 toy designed for enjoyment, not necessarily for educational purposes. You could play with it for years without learning anything more important than that the gripper opens when you turn the left joystick counterclockwise.

However, an educational adventure is waiting for anyone who delves beneath the robot's external shell. Removing the bottom plate exposes a set of mechanical gears and clutches which demonstrate how mechanical power can be transmitted through a piece of machinery from a single power source. Do you know how to construct a two-speed mechanical clutch? The Armatron provides a working example. How's your understanding of planetary gears? The Armatron gear system is a fine example of mechanical power transmission methods. It also demonstrates how appropriate gearing allows a tiny electric motor run by two D-cell batteries to move a robot arm and also lift three ounces.

The three authors of the January "Super Armatron" article saw another use for the plastic robot arm. They saw the toy as a test bed for various electronic investigations. They added a variety of electronic equipment to the Armatron so that it could be controlled by a computer. Solenoids were used to activate the mechanical pushrods which control the arm. Hall-effect and optoelectronic sensors were added to the joints and gripper to provide feedback information so that the computer could easily determine how the Armatron arm was positioned. All of this electronic equipment was then connected to a Digital Equipment Corporation LSI-11 minicomputer.

The article's closing paragraph describes why they bothered with the modification. "Although this robot arm can lift only three ounces, it provides an accurate

Continued on page 37

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Together, we can find the answers.

Honeywell

Letters

Spine Address

I am a graduate student at the University of Washington in Seattle, researching Robotic Control Theory for my PhD dissertation. I would like to receive any additional information you may have regarding the Spine robot.

Takashi Tsukamaki
17639 157th Ave. S.E.
Renton, WA 98055

Spine Robotics is located at Flojelbergsgatan 14, S-431 37 Molndal, SWEDEN.

Vision Clarification

I want to clarify a misconception in the article "Robots in Batch Manufacturing" by A. B. Bortz which appeared in the January 1984 issue of *Robotics Age*. The author describes the application of the ORS ScanSystem 2000. From the outset, Westinghouse was advised that the unit would have to be augmented with a multiple camera arrangement to reliably verify the complete complement of elements in the end bell assembly. Significantly, repeated offerings to assist Westinghouse to optimize performance were spurned. It is no wonder the results were "not entirely successful."

It is too bad that the author did not contact ORS to obtain a complete appraisal. Significantly, the same model ScanSystem 200 has been successfully

employed to verify the completeness of assembled bearing assemblies and tape cartridge assemblies.

Nello Zuech
Marketing Director
Object Recognition Systems, Inc.
1101-B State Road
Princeton, New Jersey 08540

Why Toys

In regards to your "Super Armatron" article, why bother with toys?

Gary Hodgson
Heathkit
PO Box 691
Bridgeton, MO 63044

Because...

I would like to take this opportunity to thank you for the excellent article in the November/December issue entitled "Super Armatron." It is exactly the type of article I look forward to seeing in *Robotics Age*. Rather than simply being an abstract presentation of data, it gets into the nuts-and-bolts of the project being presented. In the article is a very clear and concise description of a workable optical shaft encoder complete with the electronic schematics required for full understanding of the topic. For this and other similar reasons, I found the article fascinating—and immediately useful. I am an experimenter of sorts, and besides being the proud owner of a Tomy Ar-

matron robot, I like to tinker with other robotics-related projects. I can already envision putting the information in the article to use. Thank you again.

While on this subject, I would like to thank you for similar articles in past issues, and for the same reasons; for their immediacy and their usefulness. Two articles that immediately come to mind are: "A Homebuilt Computer-Controlled Lathe" (May/June 1981) for its wonderful information and circuit layouts concerning stepping motor control; and "A Cog-Wheel Driven Robot Cart" for its descriptions of the mechanical principles involved in this type of locomotion. Several other articles also come to mind, but I will not bore you with nonstop accolades.

As might be surmised, I enjoy the hands-on type of articles as opposed to the purely theoretical discussions. I firmly believe in the learn-by-doing approach, and that means experimentation! The aforementioned articles provide much-needed information in this regard. What I now believe would make excellent reading in a future issue would be an article (or articles) covering the practical and mechanical aspects of hydraulic power and control, in a format that would be useful to experimenters like myself, not just to those actively engaged in heavy industry. With such an article you will have covered all the bases (or at least a great number of them) while simultaneously making accessible information on the real power behind today's industrial robots. In short, I would really appreciate an article on hydraulics.

Thank you for a very enlightening magazine.
Kenneth Walker
363 High Street
First Floor
North Arlington, NJ 07032

Robots in India

I am conducting a detailed survey on robotics. Also, I wish to create awareness towards potentials of this technology in India, by starting a Robotics Institute and Robotics Clubs here. With these objectives in mind, I am contacting world top organisations, like yours, in this field. I would like to receive any information you may have on robotics and related developments.

R. D. Agarwal, MBA, BE, BSc
BA/50A, DDA Flats (MIG)
Phase I, Ashok Vihar
Delhi-110052 9 INDIA

Information Request

I am researching a paper on robotics and need all the information that I can acquire. I would appreciate receiving any information or materials which you may have.

Mary Grey
PO Box N-8549
Nassau, BAHAMAS

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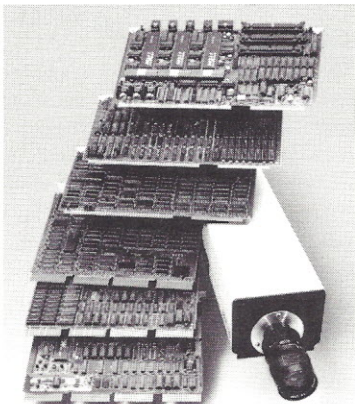
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Calendar

MARCH

March-May. The Robot Exhibit: History, Fantasy, and Reality. American Craft Museum II at International Paper Plaza, New York City. Contact: Susan Harkavy, American Craft Museum II at International Paper Plaza, 77 West 45th Street, New York, NY 10036, telephone (212) 397-0605.

The Robot Exhibit places the robot into social and historical context, tracing its nearly 5000-year development by displaying approximately 200 objects and major illustrations. Topics to be covered include: The History of Robots and Automata; Interpretations of Robots; and Working Robots. Working robots, robot sculpture, toys, prints, photographs, slides, books, and video tapes will be lent by public and private collectors, artists, designers, inventors, and robot manufacturers.

5-7 March. Applied Robotics for Industry. The Center for Professional Advancement. East Brunswick, NJ. Contact: Mrs. Edith Webb, Registrar, PO Box 964, East Brunswick, NJ 08816-0964, telephone (201) 249-1400.

The course prepares participants to make informed decisions leading to successful robotic applications. Emphasis is placed on understanding robotics technology so that potential users can analyze their requirements, evaluate robot specifications, deal with vendors, make correct selections, and install a profitable system.

15-16 March. Technology Outlook. The Wisconsin Center, Madison, WI. Contact: University of Wisconsin—Extension, Department of Engineering and Applied Science, 432 North Lake Street, Madison, WI 53706, telephone (608) 262-3748.

This seminar is for industrial executives seeking an understanding of technology, and in particular, what is likely to occur in the next five years. The seminar will focus on four primary areas: telecommunications, automation, computer advances, and genetics.

March. Applications-Oriented Approach to Artificial Intelligence, Course #9940F. Orlando, Florida. Contact: George Washington University, Continuing Engineering Education, School of Engineering and Applied Science, Washington, DC 20052. (202) 676-6106, (800) 424-9773.

This course provides an understanding of the design, application, and implementation of an intelligent system based on artificial intelligence processing techniques that are directly ap-

plicable to the solution of practical problems. The course also discusses how to choose from among the many available options in selecting or designing an intelligent system based on artificial intelligence processing techniques. The program is designed for project and design engineers, scientists, systems analysts, and technical managers who have responsibilities for specifying, designing, and implementing artificial intelligence based systems.

17 March. Florida Robotics Industry Conference. Orlando Marriott, FL. Contact: John L. Casey, Conference Coordinator, Martin Marietta Aerospace, Mail Point 530, PO Box 5837, Orlando, FL 32855.

The Florida Robotics Industry Conference is sponsored by an assembly of companies and individuals working together to foster the growth of high technology industries in Central Florida. The Orlando conference focuses on the specific needs of new firms manufacturing or utilizing robots. Speakers are drawn from both academia and industry.

19-21 March. IEEE 1984 International Conference on Acoustics, Speech, and Signal Processing. Sheraton Harbor Island Hotel, San Diego, CA 92131. Contact: Sam S. Vilone, Interstate Electronics, 707 East Vermont Avenue, Anaheim, CA 92805, telephone (714) 772-2811 X6327.

26-29 March. 1984 National Design Engineering Show & ASME Conference. McCormick Place, Chicago. Contact: National Design Engineering Show and Conference, 708 Third Ave., New York, NY 10017, telephone (212) 370-1100.

This year's show theme is *The Design Engineer's Expanding Role in Computer Integrated Manufacturing*. Computers, robotics, microprocessors, and other electronic systems will be emphasized throughout the show and conference. The conference will offer nearly 40 sessions arranged in four groups: Engineering Management and Techniques, CAD/CAM and CAE; Materials, Processes, Assembly, and Testing; and Mechanical and Fluid Systems.

APRIL

Call for papers. The Workshop on Nonmonotonic Reasoning is sponsored by the American Association for Artificial Intelligence. The workshop aims to assemble theoreticians and practitioners from across the AI field who recognize a need for nonmonotonic reasoning.

The objective is to identify those forms of plausible reasoning which arise in different areas of AI, to isolate common patterns, to entertain various accounts of these reasoning patterns, and to evaluate their suitability and limitations.

For more information regarding manuscript submission, due by 1 April, contact: Ray Reiter, General Chairman, Department of Computer Science, University of British Columbia, Vancouver, BC V6T 1W5, CANADA.

Call for papers. The National Conference on Artificial Intelligence, AAAI-84, is the fourth national conference sponsored by the American Association for Artificial Intelligence. It will be held in Austin, TX on 6-10 August 1984. The purpose is to promote scientific research of the highest caliber in AI by bringing together researchers in the field and by providing a published record of the conference. Authors are invited to submit papers on: AI and Education, AI Architectures and Languages, Automated Reasoning, Cognitive Modeling, Expert Systems, Knowledge Representation, Learning, Methodology, Natural Language, Perception, Philosophical and Scientific Foundations, and Robotics.

For more information regarding manuscript submission, due by 2 April, contact: American Association for Artificial Intelligence, 445 Burgess Drive, Menlo Park, CA 94025, telephone (415) 328-3123.

April. Robot Olympics. California State College, San Bernardino, CA. Contact: Robot Olympics Committee, Computer Center, California State College, 5500 State College Parkway, San Bernardino, CA 92407.

The first Robot Olympics will be held on a weekend in April. Sponsored by various robot manufacturers, software developers, publishers, and dealers, the weekend will also sponsor introductory and application workshops. Competitions are designed for school grades kindergarten through 12.

5-6 April. Computers and Young Children. University of Delaware, Newark, Delaware. Contact: Computers and Young Children Conference, Division of Continuing Education, University of Delaware, Newark, DE 19716.

The program is designed for teachers, administrators, and researchers in preschool and early childhood education. Hands-on workshops and speakers from the Children's Television Workshop and Apple Education Foundation are featured. An open-to-the-public Computer Show follows the conference.

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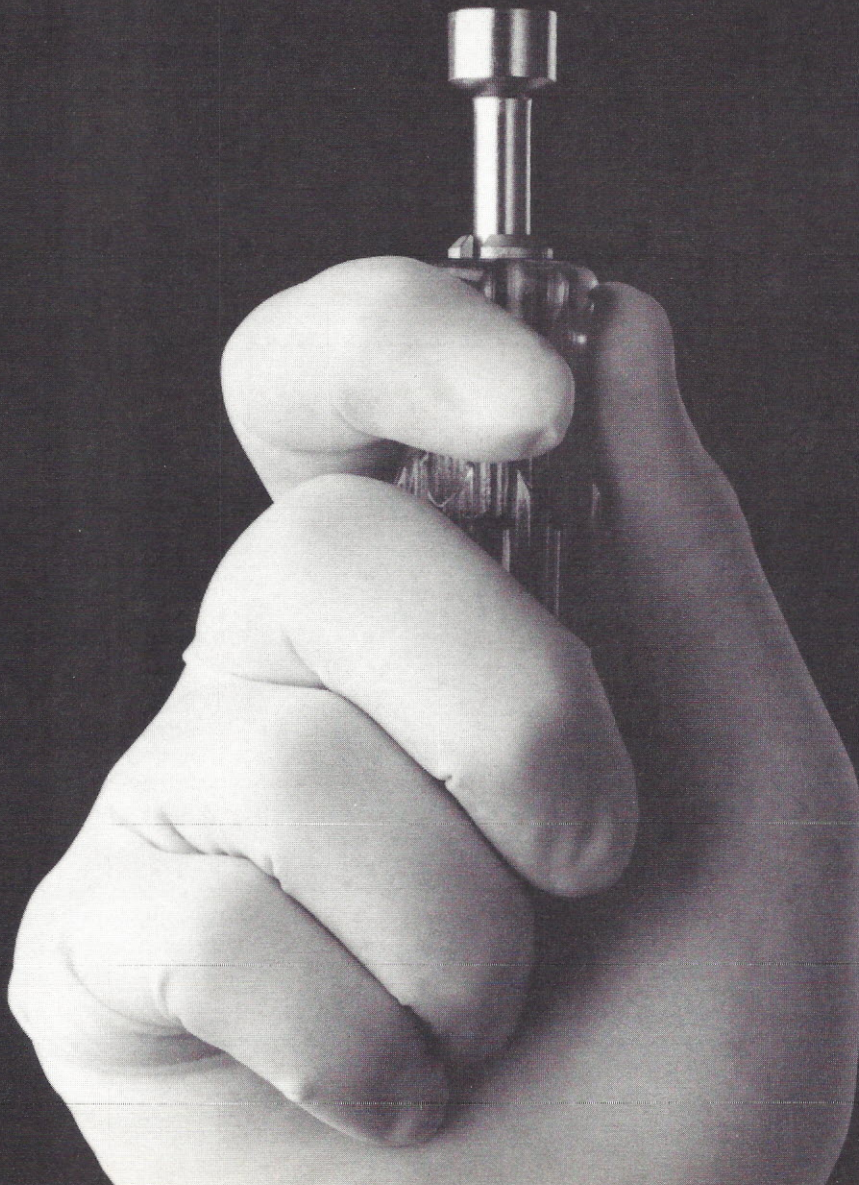
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Calendar

13-15 April. **International Personal Robot Congress & Exposition 1984.** Albuquerque, NM. Contact: International Personal Robot Congress, 1547 S. Owens St., #46, Lakewood, CO 80226, telephone (303) 278-0662.

The Congress offers displays, exhibits, seminars, a number of cultural events portraying the history and mythology of personal robots, and an opportunity for robot enthusiasts to display their creations and enter them in various robot competitions. A steering committee has been formed with representatives from Heath, RB Robot, and Androbot. Nels Winkless, robotics writer, and Russ Eberhart, robot retailer, are also on the committee.

Conference events include robot competitions, instructional sessions, and speakers such as Joseph F. Engleberger, David L. Heiserman, Nolan Bushnell, and Isaac Asimov. The various instructional sessions include hardware and software design considerations; legal issues; human services; robots in education; business opportunities; and the future of personal robots.

23-26 April. **Robotics and Remote Handling in Hostile Environments.** Sheraton Hotel,

Gatlinburg, TN. Contact: Norbert R. Grant at (615) 574-7123 or Howard W. Harvey at (615) 483-0228, or write to Technical Program Chairman, PO Box 326, Oak Ridge, TN 37830.

The meeting is sponsored by the American Nuclear Society's Remote Systems Technology Division (ANS/RSTD) and the Oak Ridge/Knoxville ANS Section. Session titles are: *History of Manipulators and Robotics; Sensory Systems; Control Technology; Manipulator and Robot Applications; Remote Systems Applications in the Nuclear Industry—Fission; Remote System Applications in Other Hostile Environments; Technology Development and Remote Systems Technology Developments at ORNL.*

24-25 April. **1984 Conference on Intelligent Systems and Machines.** Oakland University, Rochester, MI. Contact: Professor Nan K. Loh or Donald R. Falkenburg, Center for Robotics and Advanced Automation, School of Engineering and Computer Science, Oakland University, Rochester, MI 48063.

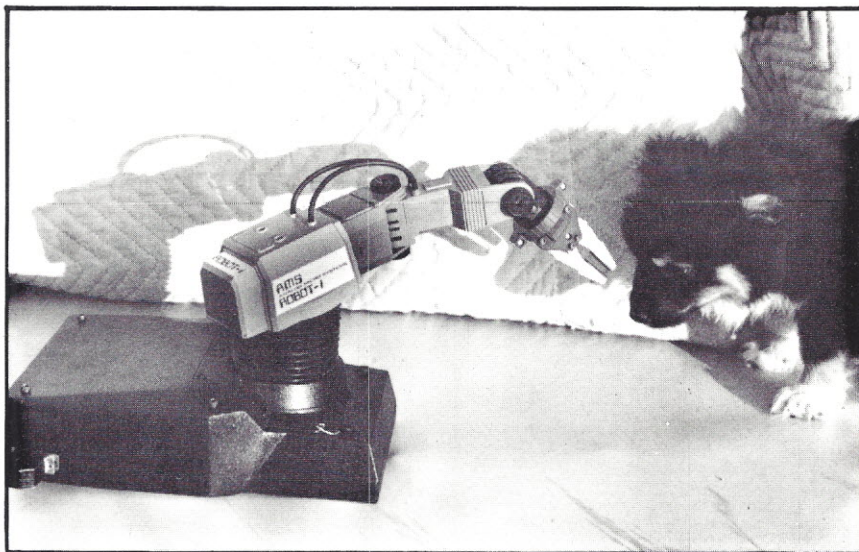
The conference will be hosted by the Center for Robotics and Advanced Automation in cooperation with sponsoring government agen-

cies and private industry. The conference's aim is to foster communication among engineers, scientists, government officials, and military services regarding issues, trends, and needs in research and development. Areas covered include artificial intelligence, hardware systems, software systems, and applications.

Applications-Oriented Approach to Artificial Intelligence, Course #994DC. Washington, DC. Contact: George Washington University, Continuing Engineering Education, School of Engineering and Applied Science, Washington, DC 20052, telephone (202) 676-6106, or (800) 424-9773.

This course provides an understanding of the design, application, and implementation of an intelligent system based on artificial intelligence processing techniques that are directly applicable to the solution of practical problems. The course also discusses how to choose from among the many available options in selecting or designing an intelligent system based on artificial intelligence processing techniques. The program is designed for project and design engineers, scientists, systems analysts, and

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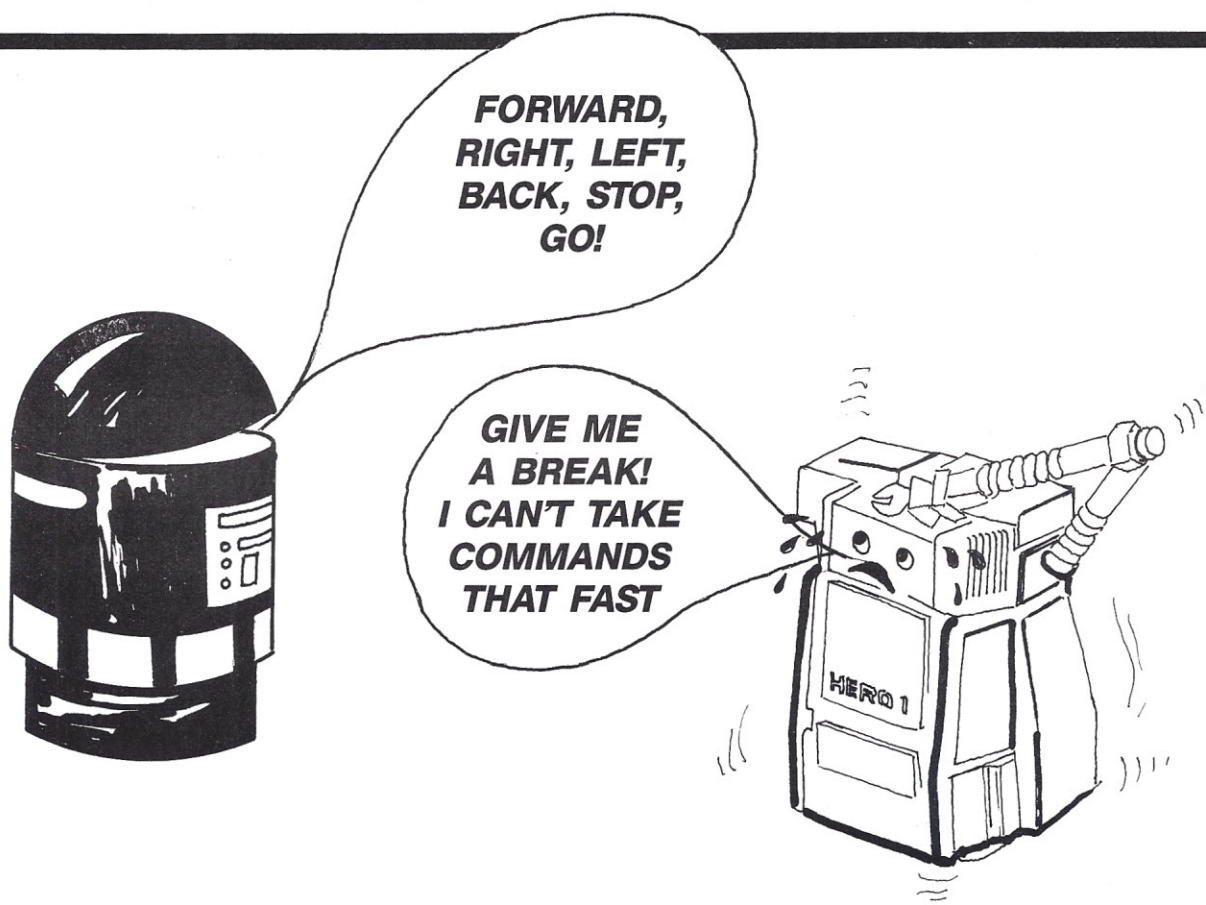
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MAY/JUNE 1982: Part Sources for Robots; An Inexpensive Arm-Hand System; The Polaroid P100 Polapulse Battery: Solution Waiting for a Problem; New Robot Books for the Bookcase: Applying Robot Vision to the Real World; Robots VI: A Landmark in an Exciting Era; Photo Essay and Notes from Robot VI.

JULY/AUG 1982: The Microbot Teach-mover; Some Notes On the Rhino XR-1 and Minimover 5; Patent Probe; Use Your Apple As a Robotics Development System; IBM Robots; Adapting a Speech Synthesizer; Constructing an Intelligent Mobile Platform, Part I.

SEP/OCT 1982: Roving Robots; Report on SIGGRAPH '82; Patent Probe No. 4,221,997; Constructing an Intelligent Mobile Platform, Part II; The Physics of One-Legged Mobile Robots.

NOV/DEC 1982: Robot Wrist Actuators; Patent Probe; A Microcomputer Based, Real-Time Robot System; The Physics of One-Legged Mobile Robots; Part II; 1982 AAAI Conference; Armatron: A Study in Arm Engineering; Invention Documentation: A Primer.

JAN/FEB 1983: The Move-Master RM-101; Mailmobiles in the Office; Teaching the Rhino XR-1 to Write; The Philosophy and Birth of Computer Science; The 2-Roll Gripper.

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JULY/AUG 1983: The Get Away Special, Part I; A Nose for the Heath Hero-1; Patent Probe: Ambulatory Platform; Robotics and the Law: Organizing the Venture; A Table of Contemporary Manipulator Devices.

SEP/OCT 1983: ODEX 1: The First Functionoid; A Cog-Wheel Driven Robot Cart; A Table of Contemporary Manipulator Devices; Patent Probe: A Portable Robot Task Analyzer; The Penpad: Handwritten Input for Computers; The Get Away Special, Part II: Flight Preparations.

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JANUARY 1984: Robots in Batch Manufacturing; Super Armatron; Directory of Robotics Education and Training Institutions; A Table of Contemporary Manipulator Devices; Patent Probe: A New Robot Patent Category; Operator Roles in Robotics; The Scorpion: Software Overview.

FEBRUARY 1984: GRASP: From Computer Aided Robot Design to Off-Line Programming; Design and Construction of a Five-Fingered Robotic Hand; Patent Probe: Omnidirectional Vehicle; Using Microprocessors with Radio-Control Servos; Designing a Reliable Voice-Input Robot Control Language; Part II, The Scorpion: Motor Control Instructions.

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Calendar

technical managers who have responsibilities for specifying, designing, and implementing artificial intelligence based systems.

MAY

7-11 May. 1984 Computer-Aided Engineering and Manufacturing Seminars and Exhibition. North Carolina State University, McKimmon Center, Raleigh, NC 27605. Contact: Alice Strickland, NCSU, Division of Continuing Education, Box 5125, Raleigh, NC 27650, telephone (919) 737-2261.

JUNE

4-7 June. Robots 8. Cobo Hall, Detroit, MI. Contact: Jeff Burnstein, Robotics Institute of America, PO Box 1366, Dearborn, MI 48121. (313) 271-0778.

Robots 8 is the eighth annual national show sponsored by RIA.

19-21 June. 3rd Canadian CAD/CAM & Robotics Exposition and Conference. Toronto International Centre of Commerce. Contact: Hugh F. Macgregor & Associates, 662 Queen

Street West, Toronto, Ontario M6J 1E5 CANADA, telephone (416) 363-2201.

This exposition is the major Canadian marketplace for advanced manufacturing systems. Conference topics include: Robotics Justification for Management, CAD/CAM, Robotics Education, Robotics Socio-Economic Considerations, Robotics Engineering, and Robotics Applications.

JULY

9-12 July. 1984 National Computer Conference. Las Vegas Convention Center, Las Vegas, NV. Contact: Ann-Marie Bartels, Las Vegas Convention Center, Las Vegas, NV, telephone (703) 558-3613.

Enhancing Creativity is the theme of the Twelfth annual NCC. The conference will focus on how the widespread availability of computing resources is altering the office, factory, and home.

23-27 July. SIGGRAPH '84. Minneapolis, MN. Contact: SIGGRAPH Conference Office, 111 East Wacker Drive, Chicago, IL 60601, telephone (312) 644-6610.

This year's SIGGRAPH Conference attendees will be treated to a vast array of technical and exhibit offerings. The program includes up to 30 one or two-day courses, panels on topical computer graphics issues, a larger number of exhibits, a design arts show, and the premier of the first totally computer-generated Omnimax film.

AUGUST

5-8 August. Lisp and Functional Programming. University of Texas at Austin. Contact: Robert S. Boyer, University of Texas at Austin, Institute for Computing Science, 2100 Main Building, Austin, TX 78712, telephone (512) 471-1901.

This is the third in a series of biennial conferences on the Lisp language and issues related to applicative languages. Areas of interest include implementation problems; programming environments; large implementations; support tools; architectures; microcode and hardware implementations; significant language extensions; lazy evaluation; functional programming; logic programming; combinators; FP; APL; Prolog; and other languages.

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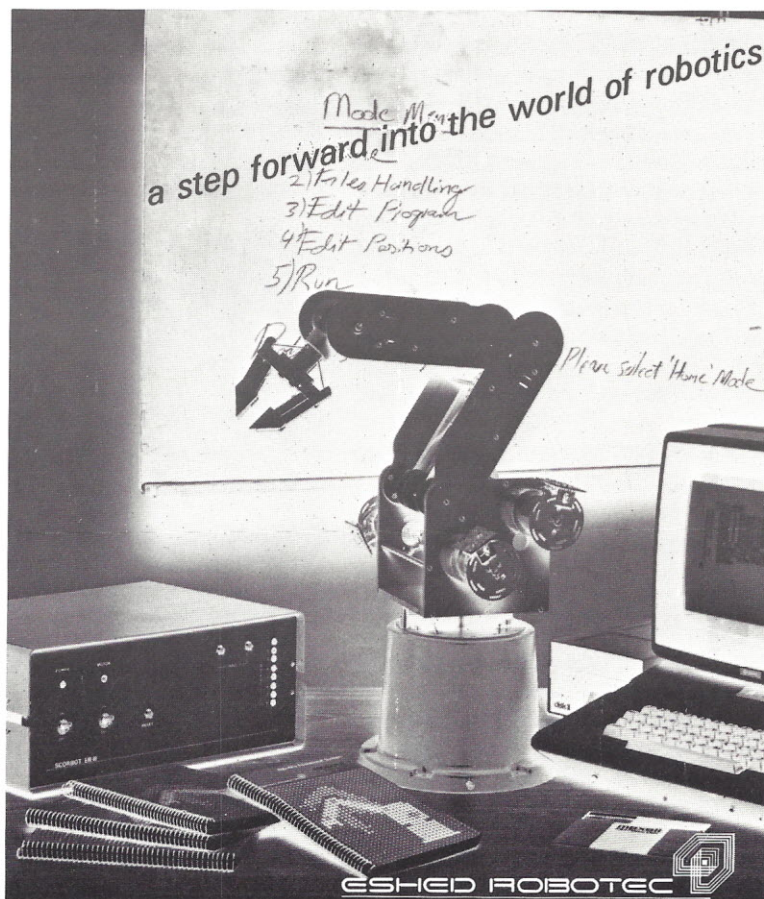
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Sensory Perceptions

COME VISIT ALBUQUERQUE. Personal robots now have a show all their own, the 1984 International Personal Robot Congress (IPRC). *Robotics Age* will cover the show's progress from April 13th through the 15th. Other expected exhibitors are drawn from companies such as Heath, Inc., RB Robot Corp., Androbot, and Excalibur Technologies. The conference has the potential to be an exciting gathering of manufacturers and designers in the personal robot industry. Invited speakers topics span the range from earth-bound facts to blue-sky speculation, including talks from Joseph Engleberger, Nolan Bushnell, David Heiserman, and Isaac Asimov.

Conference topics range from software and hardware design considerations through the use of robots in education to the legal aspects of robotics. In addition to the conferences, a robot competition will be held for both commercially manufactured and experimental robots.

ANDROBOT ALTERATIONS. Androbot, Inc. has a new president. Skip Stevely will now be guiding Androbot's products to market.

WALKING ROBOTS. The September/October *Robotics Age* cover story describing the six-legged Odetics walking machine received quite a bit of mail from people interested in the specific product as well as people building their own walking machines. One of the most interesting letters was from D. J. Todd in Wiltshire England. He included a photo of his own six-legged, pneumatically-powered walking robot. D. J. stated that this was the latest in a series of walking robots which he has constructed. We are interested to hear from anyone else designing or constructing their own walking machines.

NAVY CONTRACT. MTS Systems Corporation has been awarded a \$9.3 million contract from the Naval Research Laboratory to develop an articulating robotic system. Funding for this contract came from the Navy's Manufacturing Technology Program (ManTech). The system is slated for precision manipulation of a high-power, 25 kW laser beam which performs metalworking tasks such as welding, cutting, heat treating, glazing, and cladding. MTS of Minneapolis, Minnesota will provide robotics and associated control systems, a laser beam transport system, metalworking process control, and a precision sensor system for welding seam tracking.

EXPERT OIL WELL SYSTEM. Teknowledge,

Inc. has provided an expert system called The Drilling Advisor which provides advice on problems encountered during the drilling of oil wells. The software was developed for the French national company Societe Nationale Elf Aquitaine. The Drilling Advisor can diagnose "sticking" accidents that may occur during drilling. Sticking is a condition in which the rotary and vertical motion of the drilling apparatus is frozen, preventing further drilling or the return of the equipment to the surface. In addition to identifying the cause of the problem, the system offers advice on actions to free the drill and preventive measures to avoid a recurrence of the accident.

MISSILE FLIGHT SIMULATOR. Contraves Goerz Corporation of Pittsburgh, Pennsylvania is using an industrial robot as a key element in a new simulation facility. Complex flight control systems and development, testing, and maintenance costs demand cost effective solutions to system development requirements. Significant cost savings can be realized by computer simulation of an overall system during the design phase of new flight hardware. Simulations are used to evaluate many possible configurations and components and model the dynamics of a complete system prior to any device hardware fabrication. Once prototype flight system components have been produced, the simulation facility uses the actual hardware

elements and simulates (in real time) the entire mission, to validate the initial theoretical design for the real world variations which always occur in the transition from theory to hardware.

In the Contraves system, a seeker/guidance package is mounted on a multi-axis motion simulator. A target positioning system is mounted across from the guidance package, permitting the simulation of the target motion as well as the motion of the seeker/guidance package. This type of mission simulation is very difficult since modern terminal guidance packages (infrared, laser, and radio frequency) are becoming increasingly sophisticated in their accuracy and ability to discriminate a target. The use of a robot arm provides a flexibility and accuracy unavailable through previous simulation systems.

CONTINUOUS SPEECH. Voice recognition equipment has progressed dramatically in the last decade. Systems are now available which can recognize hundreds of different words spoken by many different people. A capability which has continued to elude speech recognition researchers is the ability to understand continuously spoken speech. Votan of Fremont, California claims to have a new system which can recognize continuously spoken speech. A technique called Word Spotting is a key feature. The system can pick out target words located anywhere within a stream of normal conversa-

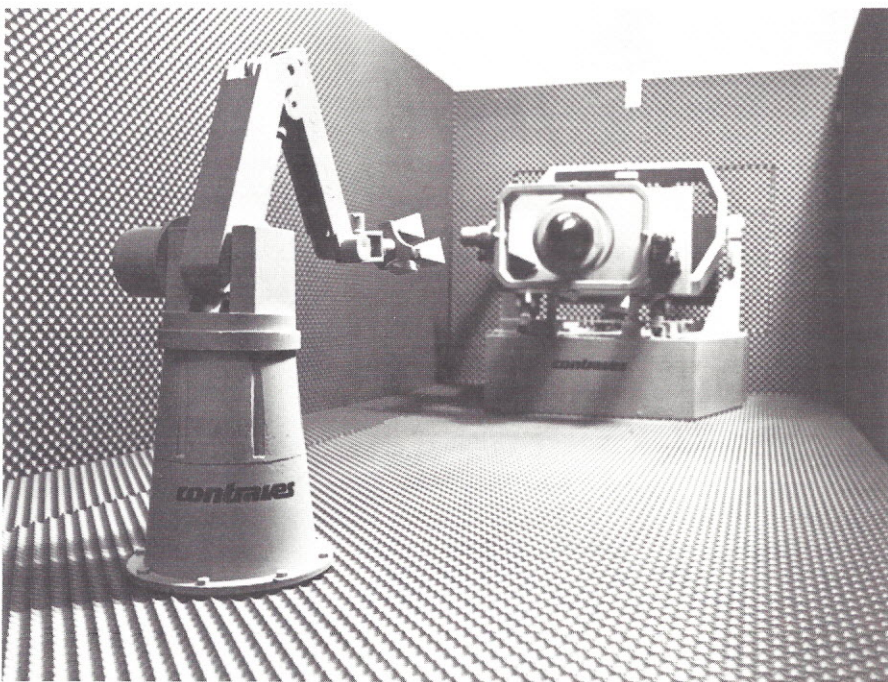


Photo 1. Robot provides cost-effective solutions for simulation systems.

Sensory Perceptions

tion. This word spotting system eliminates the need for pauses between words. Training the system to recognize continuous speech will be similar to training for isolated word recognition.

HITACHI GRIPPER. Hitachi's experimental hand uses Shape Memory Alloy (SMA) for light weight, compactness, and human-like flexibility. Made from nickel and titanium, this alloy reduces the weight of the forearm to only three pounds. Measuring 80 mm wide by 400 mm long by 50 mm high, the forearm contains fifty-four 0.2 mm SMA wires for finger actuation and eight 0.35 mm SMA wires for wrist actuation. Passing an electric current through an SMA wire causes it to shrink back to its original size. This shrinking force is used to actuate the hand.

OCTEK PURCHASED. Octek, Inc. was recently acquired by the Foxboro Corporation. The \$8 Million purchase will provide Octek with an autonomous operating environment while providing the financial strength to continue new developments. Octek will be developing and marketing a new line of machine vision systems.

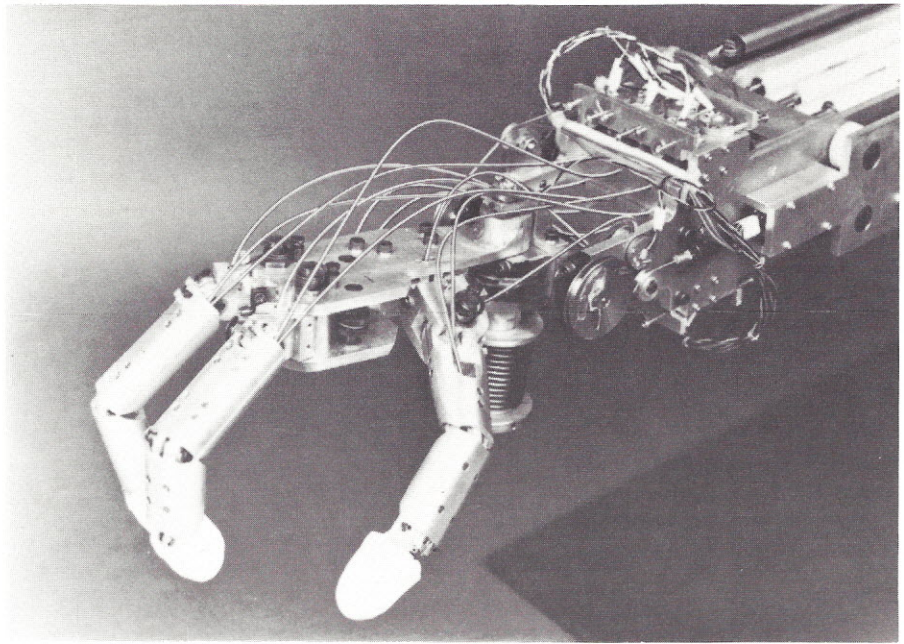
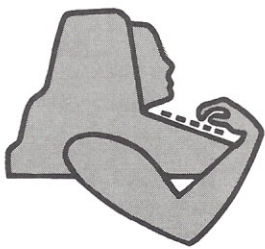


Photo 2. Shape Memory Alloy is source of gripper's power.

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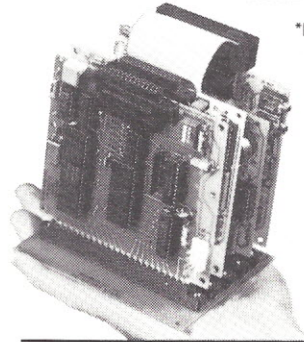


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ARMEGA 33

PART I: MECHANICAL DESIGN

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Several major objectives guided the design and development of the Armega 33 arm.

- Create a low-cost arm by making maximum use of commonly available materials and components.
- Provide an effective test bed for the development and testing of computer software for controlling manipulator arms.
- Produce a manipulator of sufficient size to provide a realistic pattern of dynamic control problems similar to those encountered in a light-duty industrial arm.

These objectives were largely realized in the design described in this article, and at a relatively modest cost.

Significant design features. One central design feature is the use of lead screw mechanisms for five of the six servos which drive the arm's movements. Lead screws have several advantages for this purpose. They can be set up to provide very strong driving forces, lock themselves into an immovable position when at rest, and provide smooth and precise movements.

Arm control is based on a closed loop system with a positive confirmation of the actual movement of all elements being fed back to the computer. In addition, the arm can be returned under software control to an index or home position at the end of a programmed routine or at any intermediate stage where this might be desirable.

Control programs for the arm can be written in BASIC. I obtained the necessary

computation speed by using a BASIC compiler.

Armega 33 is described as "human-sized." This is literally true in terms of overall dimensions. Shoulder-to-elbow length is 15 in. (38.1 cm), elbow-to-wrist another 15 in. (38.1 cm), and wrist-to-gripper pads 6.5 in. (16.5 cm). In its most extended horizontal position Armega 33 has a total reach of 33 in. (83.8 cm) which

also explains the origin of the name. The hand or gripper jaws can be opened to a width of 4.5 in. (11.4 cm).

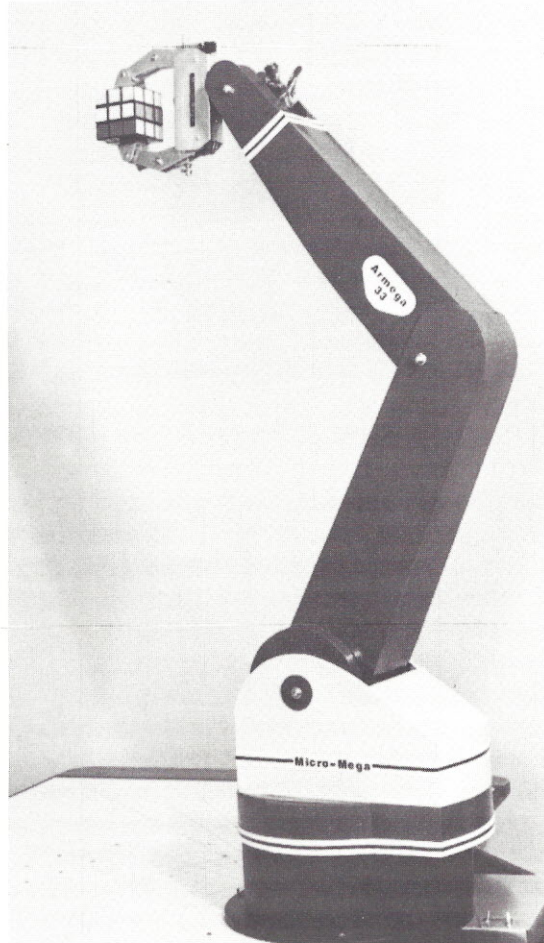
Table 1 lists the general specifications for the Armega 33 arm.

Arm Configuration. As shown in photo 1, the main structure of the arm above the base consists of truss-like elements fabricated from aluminum angle stock. The shoulder pivot, which rests on the base, supports the shoulder servo which moves in the bicep through a pushing lead screw which is always in compression. The bicep itself is an aluminum truss which supports the traveling nut for the elbow servo which moves the forearm.

The elbow servo is attached to the rearmost extension of the forearm. This is a puller servo in which the lead screw is always in tension. The forearm is a somewhat smaller aluminum angle truss, similar to the bicep. The wrist pitch servo is mounted near the center of the forearm, immediately behind a 2½ in. (6.4 cm) diameter pulley. The traveling nut is attached to this pulley which, in turn, drives a 1¼ in. (3.2 cm) diameter pulley. This

smaller pulley may be seen at the extreme front of the forearm. It is rigidly fastened to the wrist pitch bearing and rotates the hand through 180 degrees about the wrist pitch axis.

At this point it may be helpful to expand a little on some characteristics of lead screw servos. As noted earlier, lead screws can be used to provide smooth and powerful driving forces. In the Armega 33 they



Armega 33 in formal dress. The arm has been enclosed in a lightweight fiber sleeve and base cover which protects the mechanical elements as well as providing smoother contours.

Configuration—Five axes of rotation:

Body Rotation (180 degrees)
Shoulder Rotation (100 degrees)
Elbow Rotation (100 degrees)
Wrist Pitch (180 degrees)
Wrist Roll (2160 degrees)

Drive—Geared direct current motors with lead screws for Body, Shoulder, Elbow, Wrist Pitch and Hand. Geared direct drive for Wrist Roll.

Control—Closed loop using a TRS-80™ microcomputer with an 8-bit parallel interface board.

Programming Language—BASIC source program compiled with an integer compiler for increased computational speed.

Power—12V, 4A, direct current

Performance:

Element	Avg. Rate of Rotation	Average Resolution
Body	0.31 radians/sec	0.52 degree
Shoulder	0.12 radians/sec	0.35 degree
Elbow	0.18 radians/sec	0.40 degree
Wrist Pitch	0.38 radians/sec	1.11 degrees
Wrist Roll	0.72 radians/sec	1.75 degrees
Hand	3.6 seconds (full open to closed, 4.5 inches)	

Load Capacity—2.5 lbs. (1.4 kgm), at full extension.

Reach—33 in. (84 cm).

Gripping force—At stall, 5 lbs. (2.3 kg).

With spring-loaded limit switch, 1.0 lbs. (0.45 kg).

Table 1. Armega 33 specifications.

are used in every case to rotate one element of the arm with respect to another element. This is accomplished with a crank-like action in which the angle between the elements is constantly changing. At small angles the driving radius remains almost constant, but as the range of rotation begins to exceed 100 degrees, the effective driving radius (and therefore the effective force) begins to diminish rapidly. As a result, the designer must contrive to hold these angular rotations to around 100 degrees or less.

This does not present any great problem in the case of the shoulder and elbow servos which rotate a maximum of 100 degrees, as indicated in table 1. This is entirely adequate to rotate the forward end of the forearm, in the vertical plane, from below the horizontal to several degrees beyond the vertical, as shown in figure 1. Body rotation and wrist pitch rotation, however, are different matters. Each of

these rotations is required to be 180 degrees. The pulley arrangement described above for the wrist pitch servo permits this. When the wrist pitch servo drives the large pulley through 90 degrees, the small pulley fastened to the wrist pitch bearing rotates 180 degrees. A similar arrangement is used to achieve 180-degree body rotation. I will discuss this arrangement in more detail later.

To continue with the description of the arm structure—referring again to photo 1—the wrist rotation drive servo projects above the small pitch pulley directly along the vertical axis of the hand. This is the only one of the six Armega 33 servos which does not use a lead screw. It is simply a geared direct drive, but with the formidable gear ratio of 1600 to 1. With the servomotor spinning at about 12,000 revolutions per minute, the hand rotates 360 degrees in $8\frac{1}{2}$ seconds. The servo power and feedback wiring for the hand pass

through the hollow wrist rotation shaft. The hand can rotate at least three full revolutions in either direction before the wiring begins to tighten up.

The hand itself is fabricated largely from 0.032 in. (0.8 mm) aluminum sheet, and is driven by a lead screw servo which is partly visible in photo 1. The radius rods hold the gripper pads parallel at all times. In the fully open position, the hand can grasp objects up to 4½ in. (11.4 cm) wide.

Arm Construction. The most common material used in arm element construction above the base is ½ in. by ¼ in. thick aluminum angle stock (1.3 cm by 1.6 mm). A few pieces of ½ in. by ¼ in. aluminum strip are also used, together with ¾ in. by ⅛ in. thick flat aluminum (1.9 cm by 3.2 mm). The entire arm is fastened together with screws, nuts and threaded rods. The threaded rods, in sizes 6-32 and 10-24, establish the width of the truss structure for each arm element and hold the aluminum angle stock in position to develop maximum rigidity and resistance to bending stress.

Bearings, including both those for hinging the arm elements and for carrying the servo driving forces, are made of nested steel and brass tubing. Nested tubing with only a few thousandths of an inch clearance between sizes can be obtained in a variety of sizes. The inner bearing tube, in each case, is supported by a 10-24 threaded rod inserted through it and through the side members of the truss structure. To carry the servo forces or to support pulleys, a nested tubing size is fitted over the bearing tube and passes through the servo draw bars or is fastened to the pulley.

As a result of these simple construction techniques, a considerable degree of precision can be obtained with a minimum of difficult and precise machining operations. It is only necessary that the drilled holes in the side members of the trusses be in the same relative position on the left and right side members. This is easily accomplished by simply clamping them together in a drilling vise and drilling them at the same time.

It is necessary that the travelling nuts for the lead screws be accurately drilled and tapped. Actually these so-called "nuts" are not really nuts in this case, but ⅜ in. diameter (9.5 mm) aluminum rods. They are mounted between the side rails of the

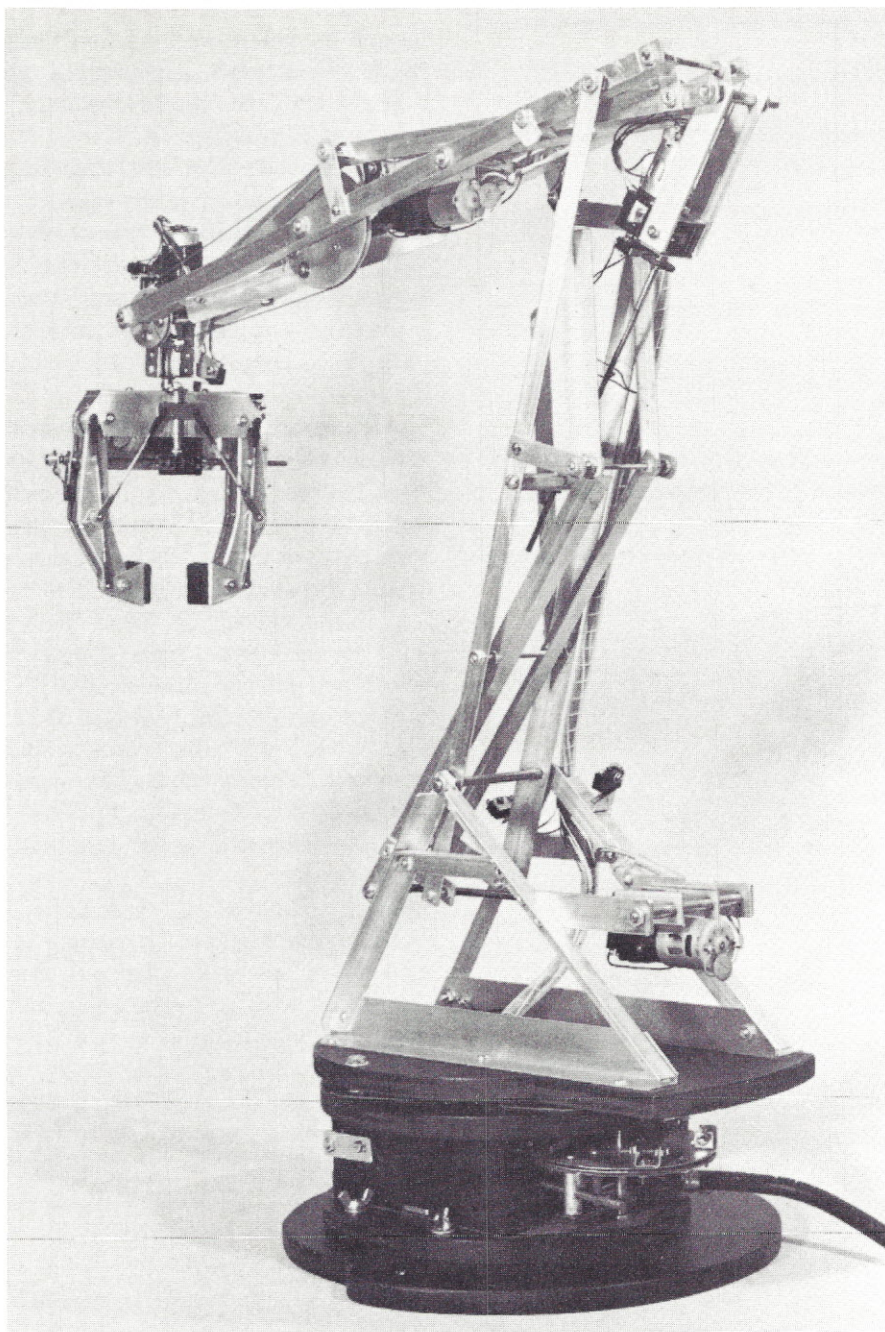


Photo 1. Armega 33, showing general structural features. Human-sized dimensions give the arm a maximum reach of 33 in.

truss structures and are supported by machine screws which pass through short brass tubing bearings pressed into the side rails and threaded into tapped holes in each end of the rods. The lead screw hole itself should be carefully centered in the rod and drilled and tapped precisely at right angles to the rod.

To ensure the entire arm assembly is accurately rigged and aligned, all that is needed is to continue to adjust the clamping nuts on the transverse threaded rods

until everything is straight, parallel and square.

The Servos. The five lead screw servos used in Armega 33 bear a strong resemblance to one another. They are all based on a popular motor and reduction gear set available at many hobby and craft shops. Drive motors are direct current permanent magnet types. The reduction gear sets and housings are of molded plastic. These have a somewhat fragile appearance but are

remarkably rugged and durable when properly shielded from the heavy thrust bearing loads. An additional modification includes keying the final lead screw drive gear to the drive shaft to resist the abrupt starting and stopping shock loads.

Photo 2 shows details of the shoulder driver servo. Note that the reduction gear housing has been enclosed in a 0.032 in. (0.8 mm) aluminum cage which is further stiffened and reinforced by the two extruded aluminum drawbars which transmit the thrust loads to the shoulder servo pivot bearing. Photo 3 is a front view of the shoulder servo giving details of the counter cam, and counter roller switch (about which, more later). The aluminum cage takes the thrust loads, both front and rear, against the steel collars clamped to the drive shaft. Brass washers are used as the actual bearing surface in each case.

The servo reduction gear housings can accommodate from one to five compound spur gears between the small brass motor shaft pinion and the Teflon final drive gear that actually rotates the lead screw. This permits gear reduction ratios ranging from 9:1 to 1600:1 between motor rotation and lead screw rotation. As a result, motors can be selected which are in the required power range and then easily tuned to give the desired rate of lead screw rotation by varying the number of compound gears in the reduction gear housing. The reduction ratios actually found most suitable for the lead screw servo motors range from 27:1

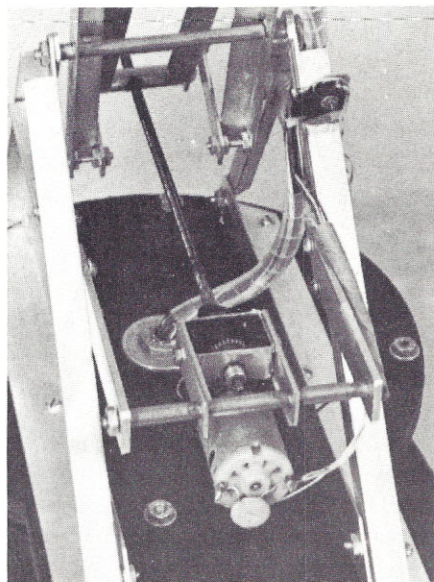


Photo 2. Shoulder servo, typical of the lead screw drives employed in five of the six servos used in Armega 33.

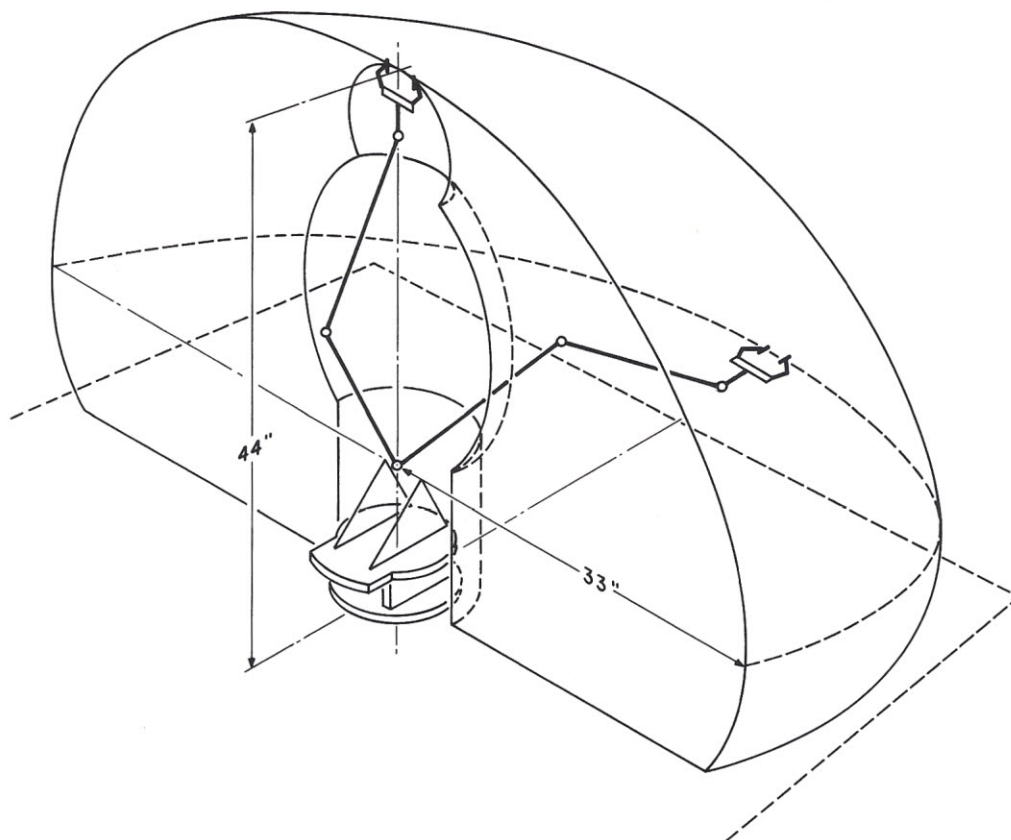


Figure 1. Swept volume diagram for Armega 33. With a maximum reach of 33 in., the arm sweeps through a semicircle $5\frac{1}{2}$ ft. (1.7 m) in diameter. Vertically, the arm extends to a maximum height of 44 in. (1.1 m). This diagram shows the total volume which can be reached by the gripper pads. The small cavity shown at the center of rotation depicts the core region, which cannot be reached. Deducting this volume from the total envelope gives a total accessible volume of more than 28 cubic ft. (0.8 cubic meter).

to 81:1. As mentioned earlier, the direct drive wrist roll servomotor uses a ratio of 1600:1.

While on the subject of servos, let's consider a problem which must be dealt with by all designers and constructors of robot devices. This is the problem of play, slack and backlash in mechanical linkages of almost any kind. It is virtually impossible to eliminate these totally, and whatever amount remains tends to limit the final level of precision with which the device can be controlled. In the case of a manipulator like Armega 33, it especially limits the ability to *repeat* movements precisely. This looseness in the total mechanism comes from three principal sources: play in the bearings which serve to hinge the major elements of the arm (bicep, forearm, wrist, etc.); play between the threads of the lead screws and the tapped holes in the traveling nuts (cross bars) through which they drive the arm movements; and backlash in the reduction gears through which the servomotors drive the lead screws.

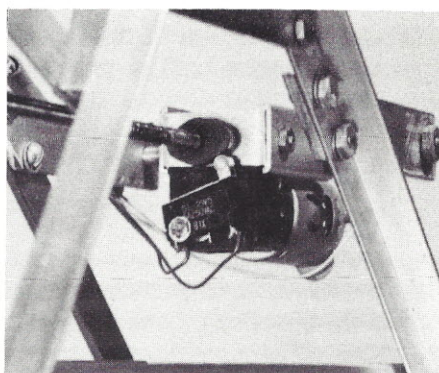


Photo 3. Front view of shoulder servo showing the counter cam and roller lever switch.

These three sources of play and backlash have each been minimized to a considerable degree in Armega 33. With respect to the pivot bearings which hinge the arm elements, at no time do these bearings undergo a major shift in the direction of the bearing load. Even when the arm is not lifting a useful load, the weight of the arm elements themselves produce

a load pattern. When handling a useful load, the bearing forces are simply increased and the direction is essentially unchanged. Thus there is no sudden up-to-down or forward-to-backward reversal which would shift the bearing clearance to the opposite side of the bearing tube.

In the case of the lead screw thread clearance, this looseness is minimized in the shoulder, elbow and wrist pitch servos since lead screws remain always either in tension (elbow and wrist pitch), or compression (shoulder). As a result, the female threads of the traveling bar always ride on the same surface of the lead screw threads whether lifting or lowering a load.

The simplest way to minimize the reduction gear backlash problem is to reduce the number of gears. This is effectively accomplished in Armega 33 through the use of the lead screw principle. The lead screw mechanism itself is a powerful form of down-gearing. The shoulder servo, for example, uses only three spur gears to produce a reduction of 27:1 between motor

and lead screw. If the servomotor itself were geared directly to the shoulder pivot, it would require a reduction ratio of almost 14,000:1, which would more than double the number of spur gears.

The Base. As mentioned earlier, the base rotation servo also uses the lead screw principle. However, the special need for precision in base rotation together with other requirements for smoothness and rigidity, created special problems in the design and construction of the base. Unlike the other servos, in which gravity minimizes lead screw slack by always keeping the driving force on the same surface of the threads, there is no such constant load at the base. In addition, rotation about the body axis is especially sensitive to rotation errors. At full arm extension all errors are magnified by the full 33 in. radius to the hand. At the same time, the base supports the whole weight of the upper arm elements themselves, in addition to any useful load that is being carried. Also, with rotation at any reasonable speed, the inertia loads become substantial during the acceleration and deceleration phases of movements about the body axis.

Accordingly, the base structure requires ruggedness and rigidity along with smooth rotation, load-bearing ability, and finally, almost no slack or play in the driving mechanism. The final structure has all these features, but went through many transitions, modifications and false starts. The base, in many respects, was the most difficult of all the mechanical elements.

The turntable element of the base, which is the actual rotating surface to which the shoulder pivot is fastened, is cut from a good grade of 5-ply plywood. This provides the kind of stiffness and rigidity needed at a number of points in the base structure. Plywood, however, is subject to some expansion and contraction with changes in temperature and humidity. As a result, it is not an adequate material upon which to depend for the critical location and alignment of the body rotation driving elements. What ultimately evolved was a kind of layered construction in which plywood is used at several levels for its stiffness, but with two steel templates sandwiched in between to establish and maintain the critical locations of bearings and shafts, etc. The lower template can be seen in photo 1 just below the large drive pulley which extends from the rear of the base. The body servo

lead screw can also be seen, in photo 1, passing through the traveling bar fastened to the large pulley.

The base uses two different types of bearings. The principal load-bearing element is a large, flat Lazy Susan™ type ball bearing with a 5½ in. (14 cm) race diameter. It is bolted between the turntable and the second plywood disk immediately beneath the turntable (see photo 1). The second base bearing is of an entirely different sort and is designed to resist the forward tilting force generated by the extended arm which would otherwise tend to put most of the down load only on the forward half of the Lazy Susan ball bearing. The vertical shaft, which rests in the second bearing at its lower end, is hollow and made from a threaded electric light fixture conduit with a 5/16 in. (8.0 mm) internal diameter. The upper end of this shaft may be seen in photo 2, below the shoulder servo, where it is clamped to the turntable with a large hexagonal nut. All of the 41 power and feedback wiring leads from the upper arm pass through this hollow shaft. The wiring is thus protected and subjected to minimal twisting from turntable rotation.

Photo 4 shows the bottom of the base. The lower end of the vertical shaft fits into the aluminum bar which serves as the bearing. The power and feedback wires are

also visible emerging from the hollow shaft. Six 10-24 threaded rods, seen protruding through the bottom plate, are used to clamp the whole base structure together.

Details of the base lead screw servo drive are also visible in photo 4. The front of the base servo is shown at the upper left of the opening just above the small 2 in. (5.1 cm) diameter pulley. This pulley, which is fastened to the hollow shaft and which actually rotates the turntable, is in turn driven through the steel cable by the large pulley which is 4 in. (10.2 cm) in diameter. The small pulley is rotated through 180 degrees when the large pulley is driven through a 90-degree angle by the lead screw.

Finally, the means for eliminating slack in the base driving mechanism was found in the use of a heavy coil spring which is seen below the lead screw in photo 4. The coil spring keeps the lead screw always in compression and thus driving on the same surface of the screw threads. This arrangement is very effective. It is also worthy of mention that despite the fact that the spring rate is 3 pounds per in. of extension (0.6 kgm per cm), there is no perceptible difference in the rate of rotation of the base whether moving against the spring or with it. This is simply another demonstration of the strong driving force developed by the lead screw.

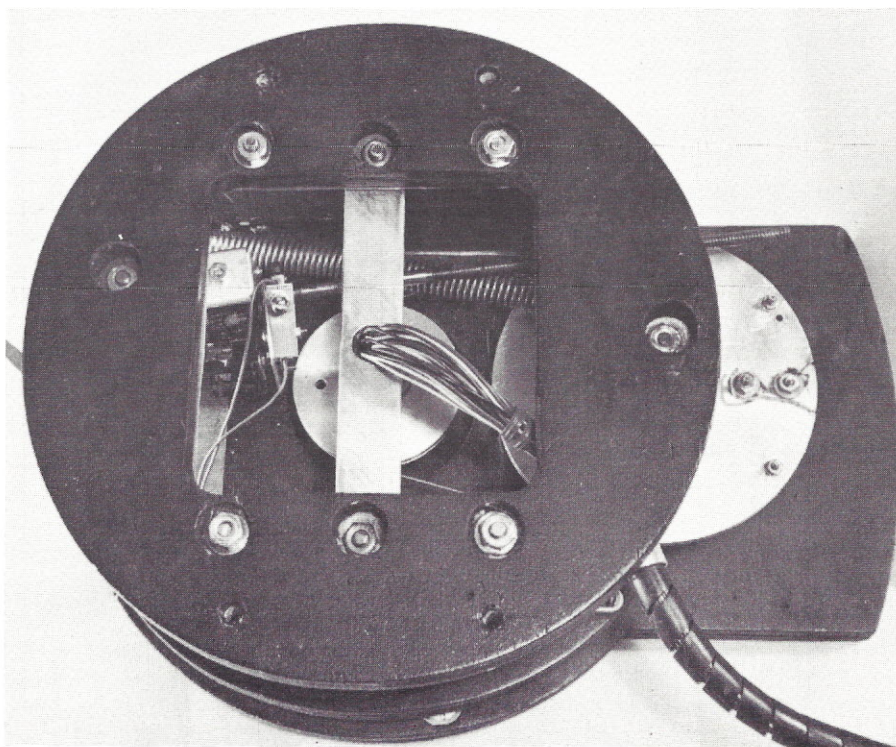


Photo 4. Bottom view of the base of the arm showing elements of the body rotation drive.

The Hand. The hand mechanism is integral with the wrist rotation drive and the entire unit rotates about the wrist pitch axis. Photo 5 illustrates this relationship. As noted earlier, the wrist rotation servo operates as a direct drive but with a very high gear reduction between the servomotor and hand (1600:1). Also visible in photo 5, just above the servo reduction gears, is the counter cam and counter roller switch for monitoring wrist rotation. The wrist rotation indexing or homing switch can be seen at the left of the wrist rotation bearing support structure just above the aluminum base of the hand (more later about these feedback switches). Six of the leads, which are visible in the wire bundle at the top of the photo, terminate in the hand itself. These six leads pass through the hollow shaft which supports the hand and thus do not interfere with hand rotation by the wrist rotation servo. As a result, the hand can be rotated more than three revolutions in either direction from the home position.

At the right of photo 5, the lever and coil spring of a spring-loaded limit switch is visible. When the hand closes upon an object,

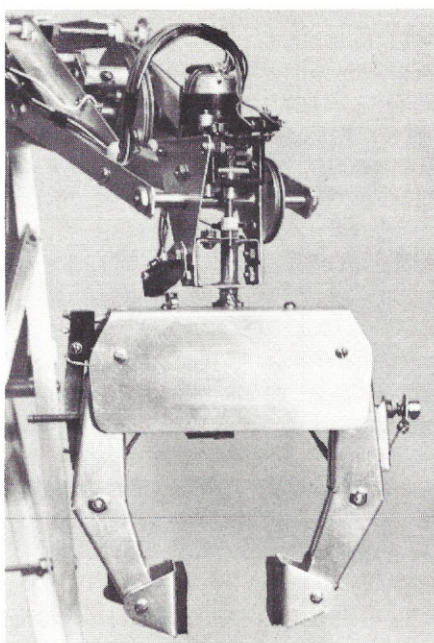


Photo 5. Top side of the hand or gripper. Maximum opening of jaws is $4\frac{1}{2}$ in.

the squeezing force developed builds up to a point sufficient to compress the spring, open the switch, and cut the power to the hand servo. The spring shown permits a

force of about one pound (0.45 kg) to be developed. Because of the nature of the lead screw drive, the hand mechanism is absolutely locked in the stopped position and fully maintains the gripping force. The hand servo is capable of exerting a force of up to five pounds (2.3 kg) between the gripper pads. Stiffer springs may be inserted to develop gripping forces up to this limit. Still another switch is visible in photo 5 at the upper end of the gripper jaw at the left. This is a limit switch which is activated when the hand is fully open and cuts the servo power at that point.

The hand itself is constructed largely of 0.032 in. (0.8 mm) aluminum sheet. Photo 6 shows the reverse side of the hand and displays details of the servo drive and tie rod linkages. The hand servomotor and gearbox may be seen partly nested in the hand base element. The lead screw extends to the right gripper arm where it passes through a short traveling rod fastened to the gripper jaw. The extension of the lead screw shaft that extends through the other gripper jaw is an unthreaded shaft which rotates freely in another

Continued on page 24

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Continued from page 21

aluminum bar. Two steel collars on this shaft impose both pulling and pushing forces on the second gripper jaw. The drive servo itself slides back and forth inside the hand base element. Two pairs of tie rods are employed in the hand. The pair which forms an inverted V and is linked to the sliding bar at the center is necessary to keep the two gripper arms at equal angles to the base element at all times. The second pair of tie rods serve to keep the gripper pads parallel to one another at all times. The gripper pads are faced with semihard rubber with a matted surface to increase friction with the object being grasped.

Arm Construction Summary. As a result of the design and construction features outlined in the preceding sections, the following significant overall features of the Armega 33 may be noted:

- Figure 1 shows the swept volume available to the arm. The total volume shown is more than 28 cubic ft. (0.8 cubic meters). Virtually all of this space may be reached by the hand except for

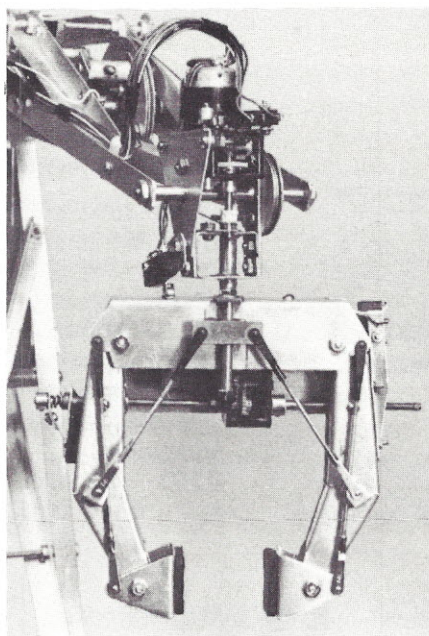


Photo 6. Reverse side of the hand, showing lead screw servo and tie rods which maintain jaw and pad alignments.

a cylinder at the center of rotation having a radius of approximately 5 in. (12.7 cm).

- The movements of all major arm elements are entirely independent of each other. There are no interactions such as those produced by certain types of cable drives.

- All elements are locked into the positions to which they were last moved. There can be no slippage as a result of heavy loads.

- The structure is quite strong and rigid against both bending and torsion loads. This despite the fact that the entire arm including the base weighs only 6½ pounds (3 kg).

Next Month. Part II of Armega 33 describes how Armega 33 is controlled by an external microcomputer.

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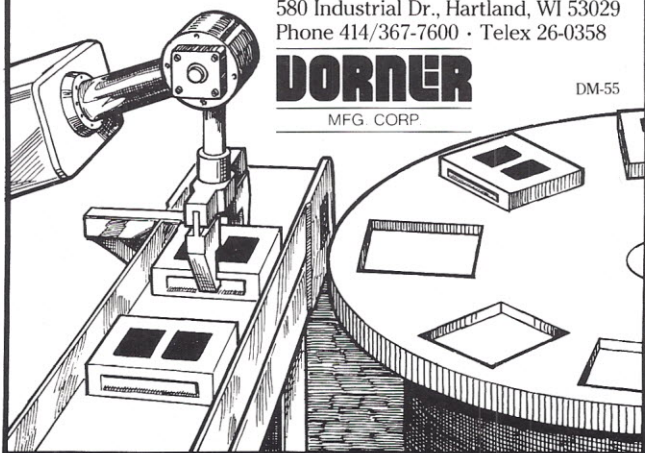
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Tesla: Man Out of Time

by Margaret Cheney

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Mark Rosheim
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If you want to read derogatory things about Edison, read a Tesla biography. *Tesla: Man Out of Time* chronicles the life and times of Nikola Tesla (1856-1947), an inventor whose scientific achievements rivaled those of his competitor, Thomas Edison. The book traces Tesla's growth from his immigration to America to his becoming one of the industrial revolution's greatest inventors.

With backing from George Westinghouse, Tesla developed his alternating current system of generators, motors, and power distribution methods, which soon replaced Edison's less efficient direct current system. This important achievement is well related in this book.

Tesla's personality and his scientific mind, which could solve the most complex problems without pen and paper, are also revealed. Tesla led a lonely and celibate lifestyle. He believed that marriage was an aid for the artist or musician, but not for the inventor. He believed inventing was an occupation that required total dedication without any distractions.

The roboticist will be interested in the chapter dedicated to Tesla's pioneering work in robotics. In 1896, Tesla wrote, "...I designed a complete machine capable of a multitude of operations, but the consummation of my labors was delayed until 1897... when first shown in the beginning of 1898, it created a sensation such as no other invention of mine has ever produced."

To the amazement of thousands of people gathered at Madison Square Garden, Tesla demonstrated a remote-controlled, submersible boat (figure 1). It was controlled by "coded pulses via Hertzian waves." Before that, he had built other remote-controlled devices, which he demonstrated to visitors in his New York laboratory.

Tesla's pioneering work in robotics warrants further study. He wrote later in his life, "I treated the whole field broadly not limiting myself to mechanisms controlled from a distance but to machines possessed of their own intelligence. Since that time I had advanced greatly in the evolution of the invention and think that

the time is not distant when I shall show an automaton which left to itself, will act as though possessed of reason and without any willful control from the outside. Whatever be the practical possibilities of such an achievement it will mark the beginning of a new epoch in mechanics."

Tesla: Man Out of Time draws upon experts in physics and engineering. The reader is given a broad sense of the history of robotics and of the frustration of a man ahead of his time, a man who predicted that "Telautomata [robots] will ultimately be produced, capable of acting as if possessed of their own intelligence, and their advent will create a revolution."

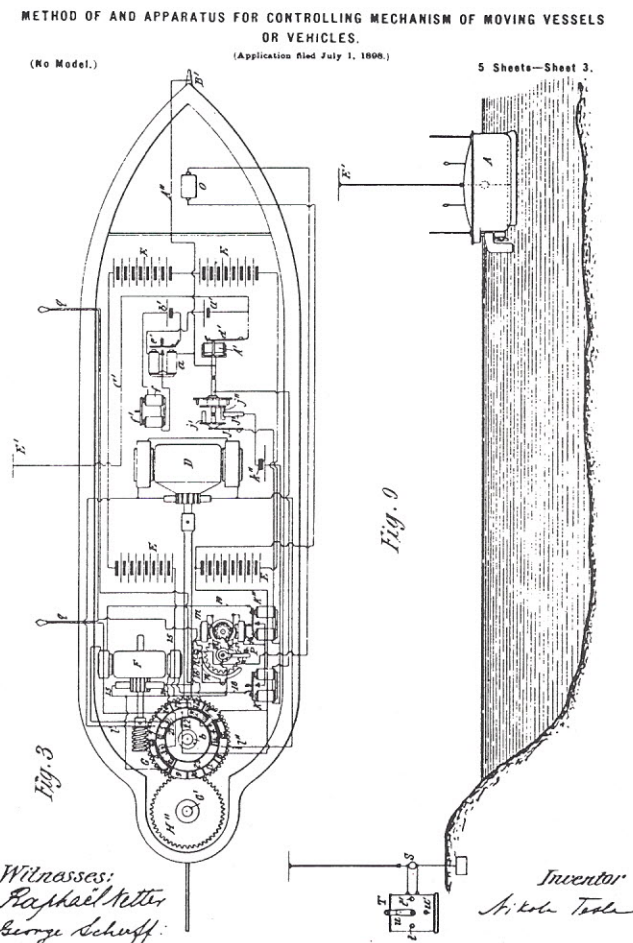


Figure 1. Tesla's remote-controlled, submersible boat, controlled by "coded pulses via Hertzian waves," which he demonstrated in 1898.

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Robot Computer Chess Game

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In 1769 Baron Von Kempelen built what was reported to be a chess-playing automaton. The machine consisted of a life-sized mannequin seated on a box in front of a chess board. The figure's hand was a pincer which could grip and move chess pieces. While the device was advertised as an automated chess playing machine, a hidden player actually made the moves.

More recently, the Summer 1979 issue of *Robotics Age* contained an article titled "The Grivet Chess Playing Arm," describing a robot arm for moving chess pieces. The article described a manipulator which could make chess moves, and which was operated by DC motors controlled by optical sensors.

Low-cost microcomputers have been used in automatic chess games for several years. These devices have been provided with a playing board, display, and keyboard. Some systems have even included voice synthesis to indicate verbally each move and condition of the game.

A Chess Playing Robot. Patent number 4,398,720 issued to Lawrence Jones, Ashley Howden, Mark Knighton, Anson Sims, David Kittinger and Richard Hollander on August 16, 1983 discloses a system that combines a robotic hand with a computer chess game. The chess game includes a board, pieces, a microcomputer,

keyboard, and an articulated robot arm. The end of the arm supports a gripper which can grasp and release chess pieces.

The chess board has switches mounted under each square for indicating the presence of a piece. Each piece contains a magnet and a complementary magnet is positioned under each square. The interaction of the two magnets assures that the pieces will be positioned at predetermined locations. The magnets also close the switches which indicate the presence of playing pieces.

The system is designed to play the game of chess with a human opponent while exhibiting emotional responses which mimic a human player. The system uses a chess-playing heuristic program such as the program *Sargon 1.0* described in the book *Sargon—A Computer Chess Playing Program*, published in 1978 by Hayden Book Company.

This program consists of:

- A chess piece move-generating section.
- A position evaluation section which generates a numeric score for game positions. The score indicates the relative strategic strength of each piece on the board.
- A material evaluation section which determines the probable outcome of attacks.

- A control section for move searching.
- A move analyzer section which considers each chess position resulting from the control section.

At each ply (set of possible moves for a turn) the move analyzer applies the material evaluator to determine if the result of the move is a better board position. The control section continues to analyze each move at each ply up to a level determined by the set skill level of play.

The Game Board and Controls. Figure 1 shows a perspective view of the robot computer chess game. A housing (2) includes a chess board and a pair of chess storage areas. A keyboard is positioned next to the chess board and provides a way to control the operation of the device. An articulated robot arm is mounted next to the board. The gripper mounted at the end of the arm has several fingers for gripping the chess pieces.

The keyboard provided keys for controlling the following functions:

Go, Take Back, Hint, Verify On/Off, Sound On/Off, Auto Play, Skill Level, New Game, Print Move, Print Board, Cancel Command, Replay, Change Color, Best Move On/Off, Emotions On/Off, Demo Program, Setup/Verify, Test Exercise, New Board, Print List, Form Size.

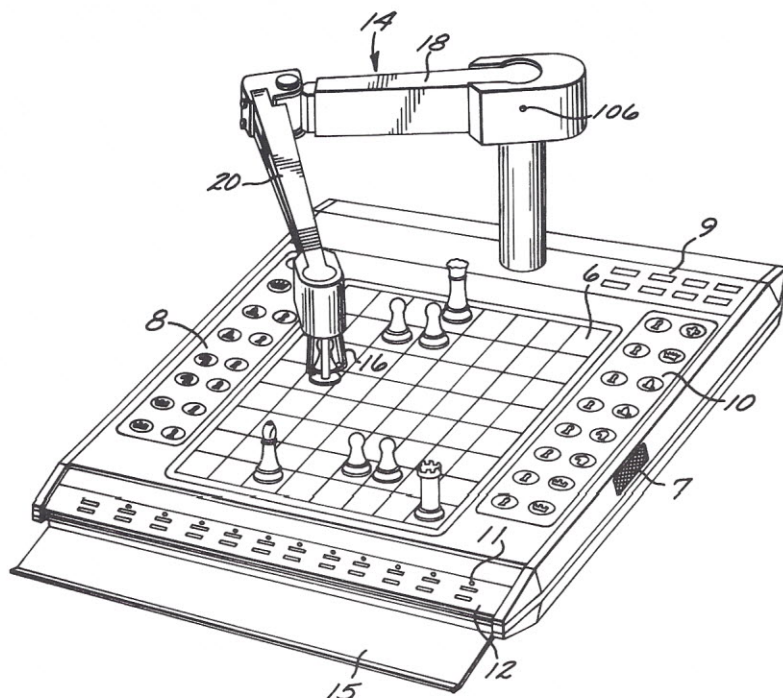


Figure 1. A perspective view of the chess-playing robot system.

Several of these keys also perform the dual function of identifying the chess piece to be moved.

The *Go* key forces the computer to make a move based on the current board position. Pressing the key while the computer is analyzing its best move interrupts the analysis process and causes the computer to make the best move found prior to pressing the *Go* key. If the key is pressed when it is the human opponent's turn, the computer will make a move for the player.

The *Take Back* key allows the player to

withdraw a move. The board is returned to its previous position. The key is effective to recall moves made by either the player or the computer.

The *Hint* key directs the computer to indicate what the program projects as the best move for the player to make. The indication is given by the robot arm moving over the chess piece and bobbing up and down. The arm moves to the final location to which that piece should be moved and repeats the up and down motion. If the key is pressed again, the robot arm indicates

the next best move.

The *Verify On/Off* key is used to test the computer's knowledge of the correct locations of all the pieces. Pressing the key turns a verify mode light on. Each piece is picked up in turn and a light flashes under the key which corresponds to the piece type.

The *Sound* key toggles the sound generation on and off. The *Auto Play* key causes the computer to play a game of chess against itself. Pressing the *Auto* key a second time returns the game to normal play.

Pressing the *Skill Level* key causes the skill level to be displayed. The robot arm is moved to a position on the board which represents a skill level. Repeatedly pressing the key causes the machine to cycle through all of the skill levels.

The *New Game Key* initiates a new game. The board is assumed to have been properly set up by the player. The *Print Move* and *Print Board* keys allow a specific move or board state to be printed on an auxiliary printer.

Most commands can be canceled by pressing the *Cancel Command* key. Those keys which toggle their functions on and off are canceled by pressing the specific key a second time.

The *Replay* key indicates the last move made by the computer by moving the robot arm between the location of the piece before and after the move. The *Change Color* key is pressed at the beginning of a game and allows selection of color. The *Best Move* key directs the computer to always select the best move. When not actuated, the computer randomly selects one of several possible moves.

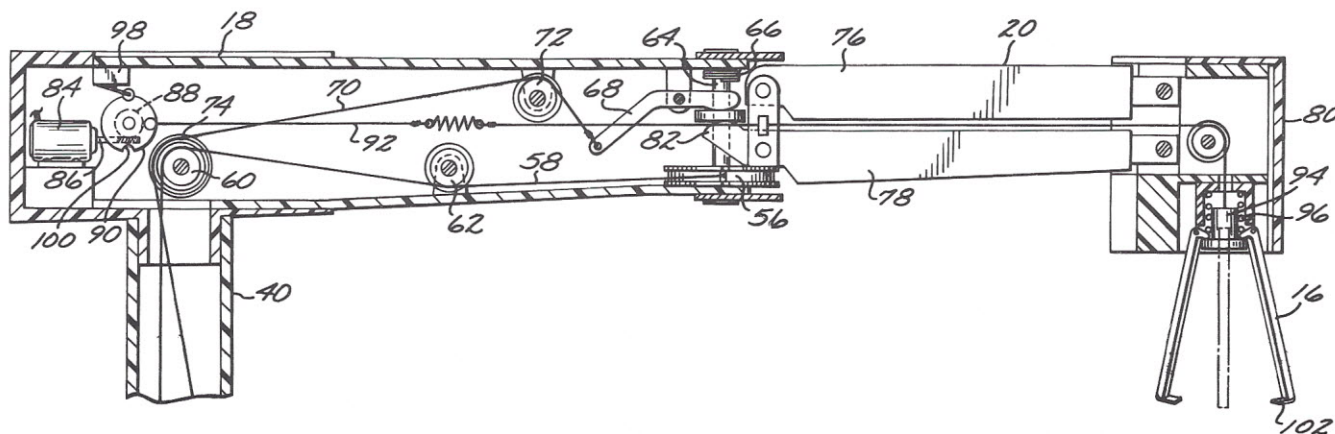


Figure 3. An interior view of the robot arm. The arm is rotated around its post by a motor within the post. The shoulder and gripper are moved by pulleys connected to motors within the chess board base.

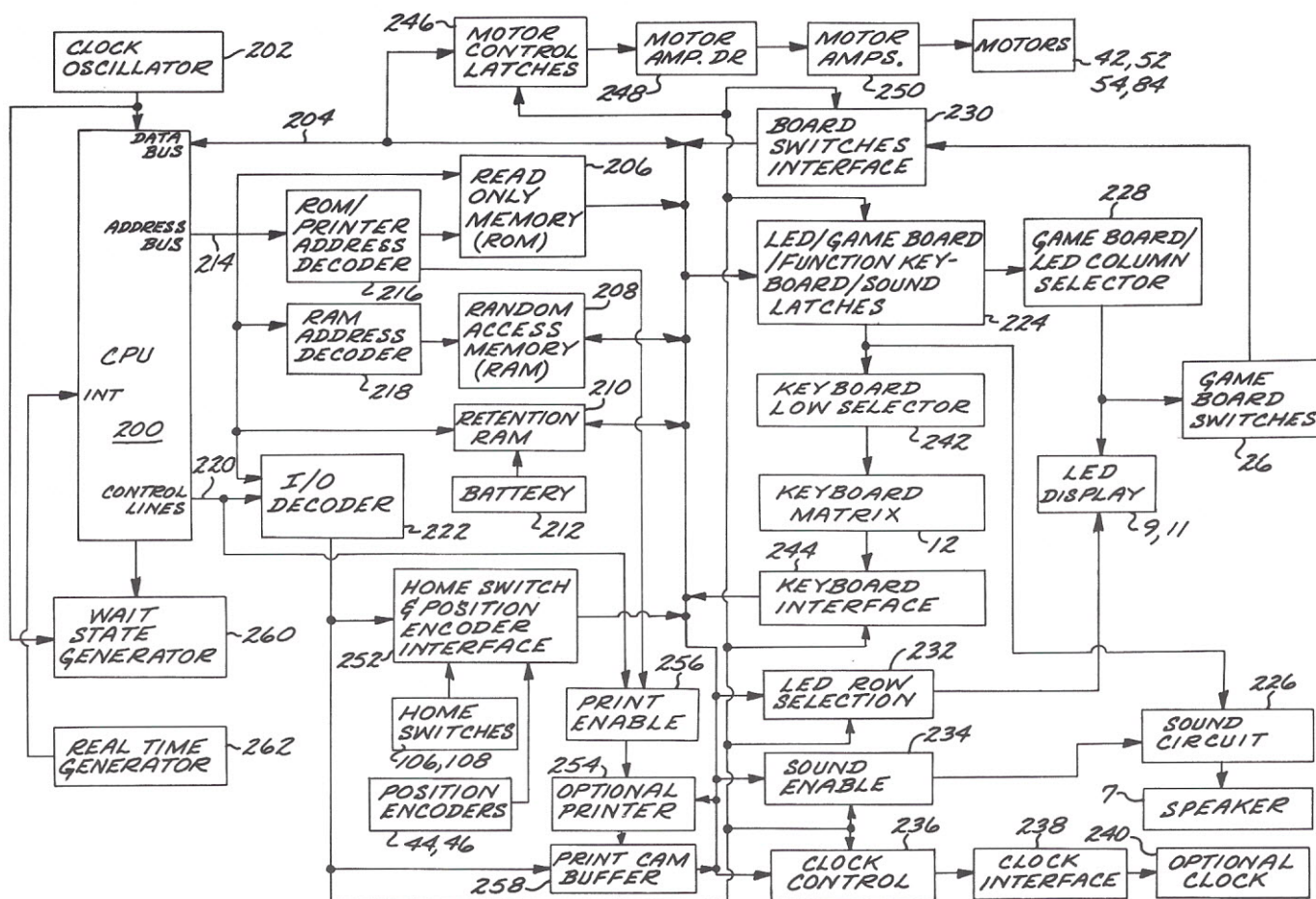


Figure 7. A block diagram describing the system electronics for the robot computer chess game.

The *Emotion* key causes the computer to display an emotional response to certain events which may occur during a game. The *Demo* key activates a stored program which shows off all of the functions of the game device.

Pressing the *Setup* key shifts the keys to their alternate functions. After pressing the *Setup* key, a specific chess piece name key is pressed. The player then places the piece on the game board. The board switch under the piece being placed is activated and the position of the specified piece is stored in the computer. Pressing the *Cancel* key terminates the *Setup* mode.

The *Test Exercise* key causes the robot arm to perform a test motion, play a tune and test all keys by lighting up their lights and sensing the keys pressed. The *New Board* key instructs the computer to automatically set up the board. Each piece is assumed to be positioned at the piece's normal beginning positions.

The Robot Arm and Computer. Figure 3 shows a cross-section of the robot arm. The robot arm is articulated and includes first and second arm portions. The first arm portion is mounted to a supporting post that allows the arm portion to rotate with respect to the game board. A DC motor is used to rotate the arm about the post. The motor is bidirectional and its angular position is detected by an optical detector. This optical detector can be formed from a pair of infrared sources occluded by a position indicator. Another pair of motors are mounted within the post. These motors drive the second arm portion via a pulley and linkage system shown in figure 3.

A fourth motor (84) moves gear (88). This motor is used to open and close the gripper (16). The fingers of the gripper are spring biased open. A microswitch (98) detects if the gripper is opened or closed.

The gripper is designed with a retention

paw that grasps the chess piece at its smallest part. The shoulder (104) serves to support each piece regardless of its type.

The central processor is a Zilog Z80B, as shown in the system diagram of figure 7. The program for performing the various functions of the system can be stored in read-only memory. The current board position can be saved in programmable CMOS memory which is kept powered by a stand-by battery.

Copies of this patent are available from the US Patent and Trademark Office for \$1.00 each. Orders for patents should be sent with payment to: Commissioner of Patents and Trademarks, Washington, DC 20231.

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THE SCORPION

PART III: COMMANDS WITH RESPONSES

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The previous two articles in this series have discussed how the Scorpion was designed, and described the first half of the Scorpion's instruction set. Part three, the last in the series, discusses the second half of the instruction set and describes how to extend the language.

Resetting the System. To avoid having to leave an externally connected terminal every time you need to reset the Scorpion, a reset instruction is provided. The "/IR" instruction is used to reset the Scorpion.

The reset instruction initializes all programmable memory and returns the system to power-up condition.

There will be situations during which the system cannot be reset through software. The reset instruction will not work if the operating system branches out of the loop that scans the UART for incoming characters or if the operating system has been adversely modified.

Set/Clear the Master I/O Byte. To conserve battery power, we have provided the ability to shut off all extraneous devices using power. This feature is controlled through the Master I/O byte.

Setting the Master I/O byte to hexadecimal "00" permits all I/O operations. Setting this byte to hexadecimal "FF" inhibits all I/O operations. The most significant bit overrides all other bits. Setting the most significant bit to "1" inhibits all other bits. The eight bits are assigned as follows:

- Bit 0—Speaker.
- Bit 1—Eyes.

- Bit 2—Lamps for ground tracker.
- Bit 3—Horizontal scanner.
- Bit 4—Vertical scanner.
- Bit 5—Left drive motor.
- Bit 6—Right drive motor.
- Bit 7—Master bit. Overrides all others.

Changing the value of any bit from "1" to "0" allows that device to operate. Setting the byte to "00" allows everything to operate. If bit seven is "1," all devices are inhibited. Thus, all activity can be inhibited independently of setting each bit.

The instruction for modifying the I/O byte is defined as "/3Yhh" where:

- "/" indicates a new instruction.
- "3" indicates three bytes will follow.
- "Y" indicates the I/O byte.
- "hh" indicates the hexadecimal value to be stored in the Master I/O byte.

Obey/Ignore Master I/O Byte. It is sometimes necessary to ignore the Master I/O byte status. This can be done with the "/3Zhh" command which is interpreted as follows:

- "/" indicates a new instruction.
- "3" indicates three data bytes follow.
- "Z" indicates the Obey/Ignore command.
- "hh" indicates the hexadecimal value of the bits used to determine whether the Master I/O byte is obeyed or ignored. Each bit of the "/3Zhh" command corresponds to a bit in the Master I/O byte. Setting a bit in the "/3Zhh" command to "0" means to ignore the corresponding bit in the Master I/O byte, setting the bit to "1" indicates the bit

should not be ignored.

Moving Motors a Specified Amount. In part two, I described the speed control command which is used to turn on a motor and keep it running. Another command exists for moving motors a specific number of steps.

The instruction for moving the left motor is similar to "/8Cdff####," where:

- "/" indicates a new instruction.
- "8" indicates eight data bytes follow.
- "C" indicates the right motor is to be moved.
- "d" indicates the direction of travel ("+" or "-").
- "ff" indicates the speed at which the motor is moved ("00" to "99").
- "####" indicates the number of steps that the motor is to move ("0000" to "9999").

The instruction for moving the right motor is similar, except that the "C" is replaced with a "D."

If the specific move instruction is received while a motor is running in continuous mode, the following actions occur:

- A flag is set which indicates that the specific move mode is in effect.
- The specific move is initiated and completed.
- The flag is cleared indicating that the system is back in continuous move mode.
- The motor continues turning as before. The count indicating how far the motor has moved is not disturbed since the specific move is not added to it.

This software design means you can execute a 90-degree turn in the middle of a continuous move. The turn can be executed either forward or backward. This is a very useful maneuver within collision recovery or obstacle avoidance routines.

The Questions. In addition to motion control commands, we can ask the Scorpion questions about its system. When we give the Scorpion an instruction, the response comes from the electromechanical part of the system. When we ask a question, the response comes in the form of information that is received at the computer's RS-232 port. When we ask a question, we must be ready to receive an answer.

Reading Microswitches. The bumpers which surround the Scorpion are attached to a set of microswitches. When a microswitch is closed, the computer shuts off all energy to all output devices. This is done to conserve battery power and to protect the Scorpion from damage. The shutoff is accomplished by setting bit seven of the Master I/O byte to "1." Whenever the value of this bit is "1," all output to the speaker, eyes, tracker, and motors is inhibited. However, you can still communicate with the host computer over the RS-232 line. When bit seven of the Master I/O byte is set to "0," all output returns to its original state.

To recover from a collision, we must first decide on a recovery procedure. The Master I/O byte must be ignored since the microswitch will keep turning the system off. We can now back the Scorpion away from the obstruction and maneuver it to a position where it will not hit the obstruction again. Once the recovery is complete, we reset the Master I/O byte and start obeying it again.

The instruction to interrogate the microswitches is "/B." The Scorpion responds with the phrase "Bhh." "B" indicates an answer related to the bumpers and "hh" represents bumper data as one hexadecimal byte. Each bit in the byte represents one of the eight microswitches.

Reading the Scanner Buffer. The infrared scanner is read by reading the scanner buffer. The question returns the contents of the scanner buffer. Part two of this article described the Scan instruction used to move the scanner motors and enter the data into the scanner buffer. The Scan instruction also determines the number of

valid bytes that are in the buffer. For example, if a scan of 15 was requested from the horizontal scanner, the scanner buffer will contain 31 valid bytes of information.

The instruction for requesting the scanner buffer contents is "/S." The Scorpion responds with "Sdhhhh..." where:

- "S" indicates a scan response.
- "d" indicates the scan direction, "H" for horizontal or "V" for vertical.
- "hh," each byte pair represents a single hexadecimal value. From one to 199 bytes of data may be returned, depending on the length of the previous scan.

Reading the Eyes. The instruction for reading the eye values is "/E." The Scorpion responds with "E#," where:

- "E" indicates an eye response.
- "#" is an ASCII character which indicates the status for both eyes. "0" means both eyes are off, "1" means only the right eye is on, "2" means only the left eye is on, "3" means both the left and right eyes are on.

Reading the Tracker Lamps. The instruction for reading the tracker lamps is "/G." The Scorpion answers "G#," where:

- "G" indicates a tracker lamp response.
- "#" is an ASCII character which indicates the status of both lamps. "0" means both lamps are off, "1" means both lamps are on.

Reading the Ground Tracker Phototransistors. The instruction for reading the phototransistors is "/T." The Scorpion responds with "T#," where:

- "T" indicates a ground tracker response.
- "#" is an ASCII character which indicates the status of the phototransistors. The returned values are similar to that returned when the eye status is requested.

Reading the Motor Move Status. The instruction for reading how far the motors have moved since the last motor interrogation is "/M." The Scorpion responds with an answer which looks like "Ms####s####."

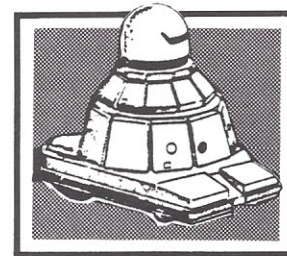
- "M" indicates a motor response.
- "s####" each group of five characters indicates the direction "s" and number of steps "####" moved since the last interrogation. The first group contains information about the left motor and the

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The motor count registers are cleared after each interrogation. However, the Scorpion does remember the last move, just in case a transmission error occurs. This value can be read with a RAM Read instruction.

The instruction for reading the Busy Byte is "/IX." The Scorpion responds with "Xhh," where:

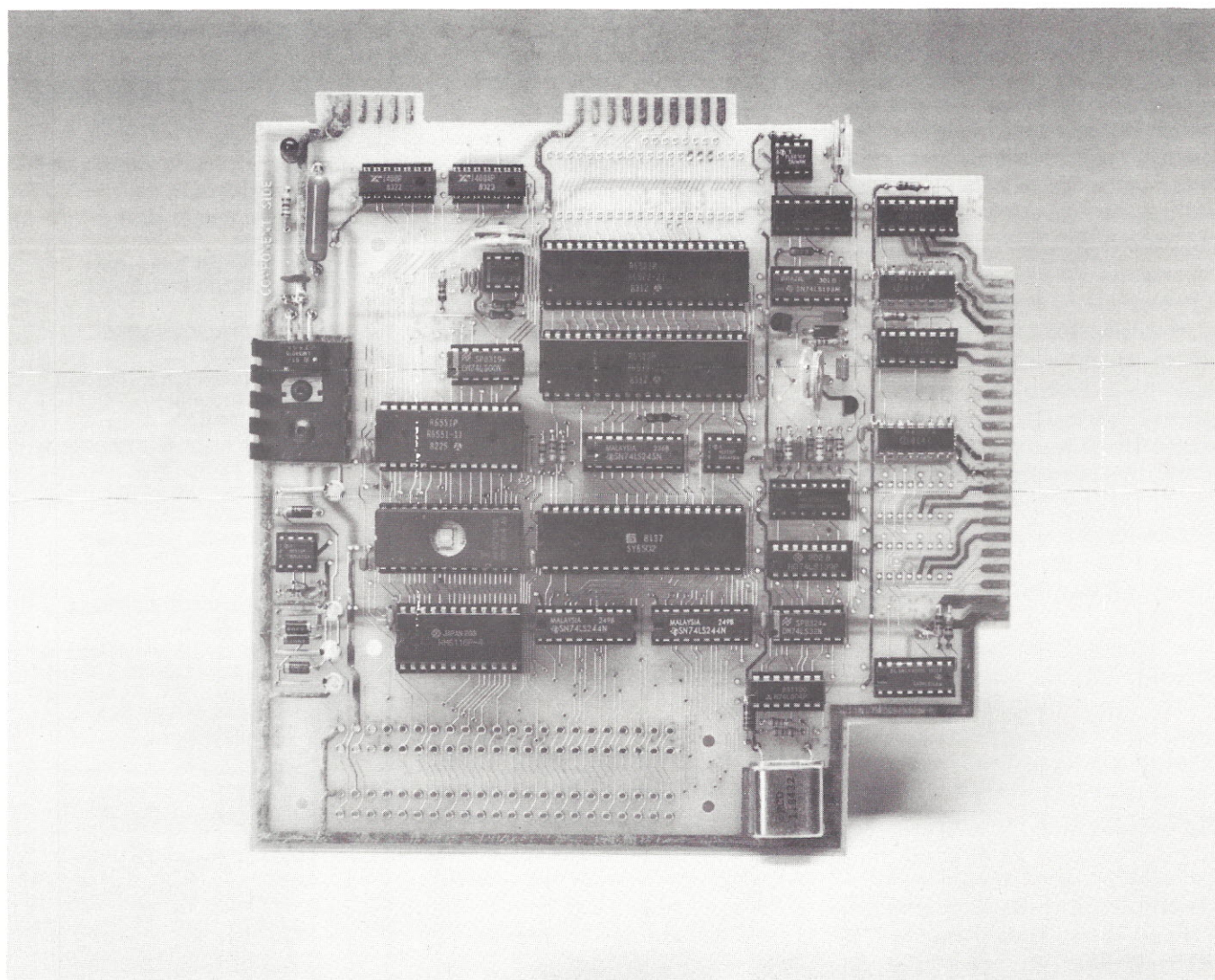
Each bit in the returned data byte represents a particular function. If the bit is set to one, then the function is in progress. If the bit is set to zero, the particular function is not in progress. The eight bits are defined as follows.

- Bit 0—speaker tone in progress.
- Bit 1—at least one eye is on.
- Bit 2—the ground tracker lamps are on.
- Bit 3—the horizontal scanner is scanning, moving, or resetting.
- Bit 4—the vertical scanner is scanning, moving, or resetting.
- Bit 5—the left drive motor is on.
- Bit 6—the right drive motor is on.
- Bit 7—something is going on.

This information is useful to determine when a scan or some other activity is completed so the next scan or activity will not overrun the one in progress.

- “I” indicates an instruction.
- “7” indicates seven bytes of data follow.
- “R” indicates the memory (RAM) interrogation question.
- “aaaa” indicates the hexadecimal starting address in memory.
- “###” indicates the number of bytes to be read.

The Scorpion responds with:
"Rhhhh...."



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where:

- "R" indicates information coming from memory locations.
- "hh," each byte pair represents a single hexadecimal value. The value represents the data contained in the memory locations.

Reading the Remaining Motor Move.

When we are using a specific move command to move a motor a specific number of steps, we must have a way to determine when the move is complete so that we will not send the motor another move command until it has completed the first. The "1C" instruction is used to determine how many steps are left until the left motor is finished. The "1D" instruction returns similar information for the right motor.

The Scorpion responds with "C####" for the left motor and "D####" for the right motor. The four digits, represented by "####", indicate the number of steps still remaining for this motor. This number can range from "0000" to "9999".

Reading the Entire Machine. Since the Scorpion maintains the status of all parameters, an instruction has been provided which reads *almost* all parameters at once. The optical scanner data and memory data are not returned. This instruction, "1P", allows almost all processing to be done at the host computer in one step.

The Scorpion responds to the "1P" command with the answer

"PBhhE#G#T###Ms####s####

YhhXhhC####D####"

The "P" indicates all parameters are being returned. Each individual parameter is returned as described previously.

Language Extensions. Though it's fine to play with a machine that is all designed and laid out in front of you, the real fun comes from modifying the basic elements to your own liking. In order to do this, you must be able to modify the system hardware and software. We have made every effort to allow for easy modifications to the Scorpion. Of these modifications, the most interesting is probably the ability to modify the operating system.

The Scorpion can be sent commands which are appended to the built-in instruction set. When the Scorpion computer receives an unknown command, the command processing loop eventually ends up

at a routine which assumes that the current instruction is an error. The erroneous instruction is then cleared and the routine jumps back to the top of the control loop. Since all unknown commands eventually reach this point, we can add new commands at this point.

The part of the control loop code which is contained in programmable memory can be altered with the "7R..." command. You have to design the necessary 6502 code and provide the appropriate command interpretation and response. After you are done, you must provide the appropriate jump commands to re-enter the main control loop.

This ability to extend the language is necessary because the mother board provides places for connectors that allow the entire system bus to be extended to other peripheral cards. These cards may have a host of sophisticated capabilities ranging from distance sensing equipment to large memory banks. The simple method of altering the instruction set provides a way to control these external functions.

Your Own Operating System. In addition to extending the language instruction set, you can also create your own operating system for the Scorpion. This is an excellent exercise for anyone interested in robotics. The Scorpion provides tools for developing your own operating system in programmable memory without altering the original operating system stored in read-only memory.

The Scorpion is a versatile educational tool which can be used for simple experimentation with a roving robot or in-depth exploration of a robot's control structure.

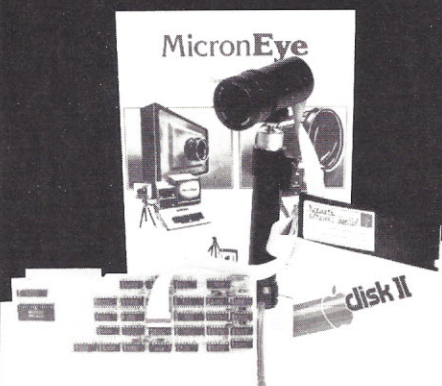
The software for the Scorpion was designed by Foad Rekabi, BSEE, University of Illinois. The computer hardware was designed by Bob Syeszycski, BSEE, University of Illinois. The Scorpion's overall design was the responsibility of H. S. Sandhu, BS, MS, University of Illinois.

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A Simple Computer Interface for Robotics Experiments

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Ventura, CA 93004

If you wish to experiment with robotics but lack a big budget, here is a simple, inexpensive computer interface with which you can start. When you add the circuit described in this article to your computer's latched parallel port, you can control small DC motors, electromagnets, relays, and other devices used in constructing robotics projects. The circuit assembly is straightforward and the parts are readily available.

The circuit, shown in figure 1, is built around the 2N2222 silicon power transistor, which can handle up to 800 mA of collector current. This makes it ideal for driving small DC electromechanical devices using only the TTL output from the computer. The transistor acts as a switch which turns on or off in response to the data bits sent to the computer's eight-bit parallel port. This allows you to control external devices directly from within your software.

Figure 1 illustrates how a 2N2222 transistor can be connected to your computer. The transistor's "base" is wired to a single data line of the parallel port. The data line is logically high or low (1 or 0), depending on the byte of data most recently written to the parallel port. For example, when bit D_0 is high, meaning it has a voltage greater than 3 V, a small amount of current flows from the port to ground through the 2N2222 base-emitter junction. This current activates the transistor's collector-base junction which allows up to 800 mA to flow

from the computer's $V+$ voltage source through load resistance, R_L , and back to ground through the collector. The transistor switch is now on.

When D_0 goes low, meaning it has a voltage less than 0.5 V, there is no potential between the transistor base and ground, so no current flows from the port's data line. This, in turn, means that no current can flow through the collector or the load resistance. The transistor switch is now off. The load resistance, R_L , is any DC device you wish to control. By connecting the base of one 2N2222 to each bit in the parallel port, up to eight devices can be actuated by placing the appropriate data byte in the port's memory location.

Figure 2 is a circuit diagram of a general purpose motor control interface using the 2N2222 transistor. Notice that the 2N2222 connected to data bit 1 is used to activate a DPDT relay. This wire reverses the polarity of the power connections with respect to the motors being controlled, allowing the direction of the motor to be controlled with software. Two 2N2222 transistors are required for each motor. They are configured so that one will always act as a switch, no matter which polarity has been selected for the motors. Additional motors can be controlled by wiring transistor pairs in parallel to those shown.

The coil for an electromagnet, connected through a 2N2222 outside the

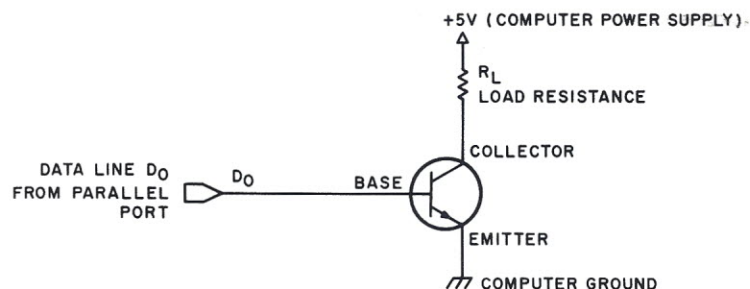


Figure 1. This simple interface, based on the 2N2222 transistor, can be used to control electromechanical devices such as small DC motors, electromagnets, and relays. The transistor can handle up to 800 mA of current. The value R_L , shown in the diagram, represents the device to be controlled.

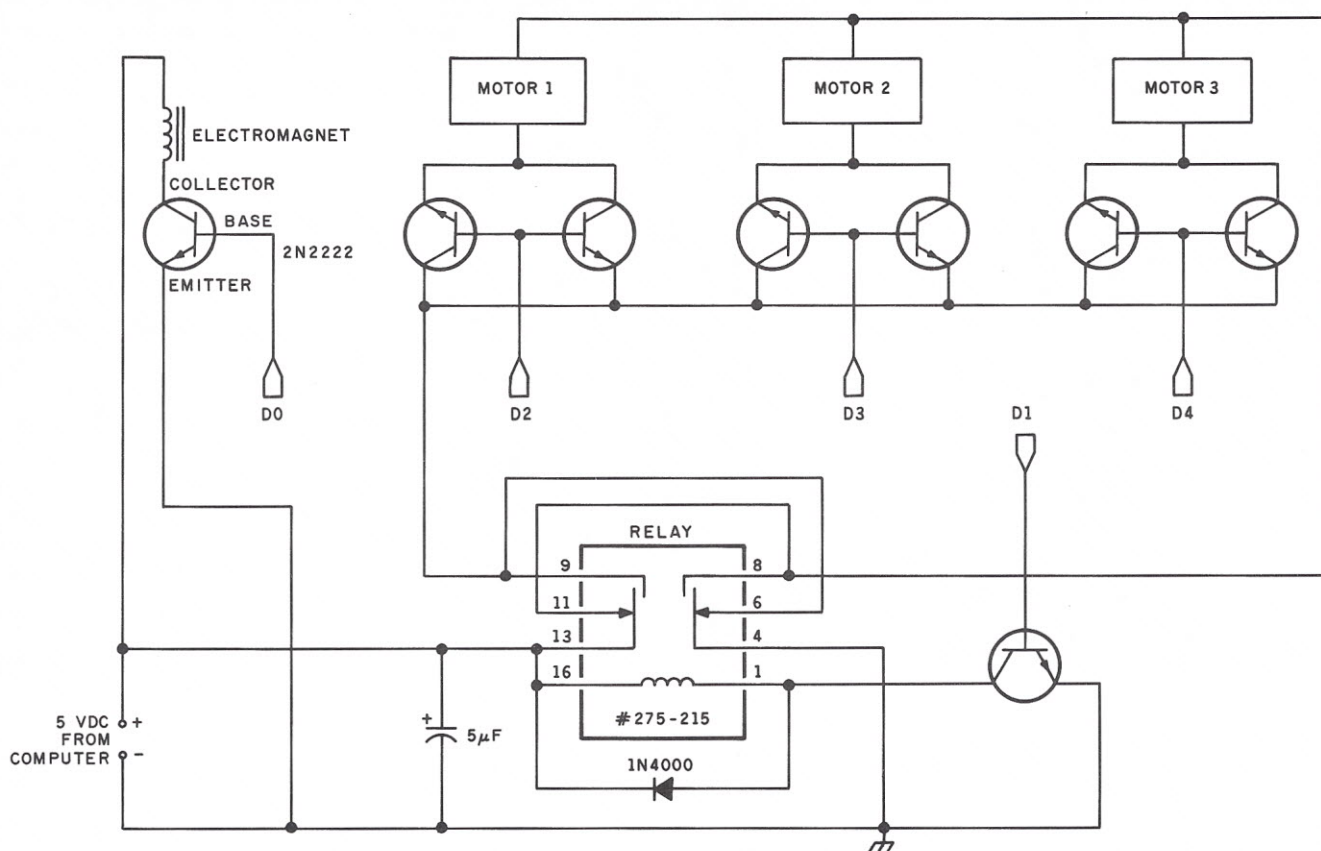


Figure 2. A general-purpose motor control interface. This simple control interface allows three motors and one electromagnet to be controlled from a single eight-bit parallel port. Data bit D_1 controls a relay which is used to reverse the motor direction. All transistors shown in this circuit are type 2N2222.

motor control circuit, is also shown. This allows the magnet to operate continuously, even when the motor polarity is being reversed by the relay. Additional devices could be wired in parallel using a 2N2222 transistor interface.

Table 1 contains the parts list for constructing the control circuit shown in figure 2. This circuit can be assembled in about two hours from parts obtained from any electronics supplier. The relay is available in a 16-pin DIP package. The entire circuit fits nicely on a small plugboard.

Always remember to use a heat sink when soldering the 2N2222 to the board. Also, don't leave out the diode and electrolytic capacitor. Although the circuit will function without them, there will be more transient voltages introduced into your system, which could affect computer operation. If your computer's parallel port can't furnish sufficient current to the base of the 2N2222, a 74LS240 bus driver IC can be connected between the data lines and the transistors to increase the current flow to about 20 mA for a logic 1. Note that this

will invert the output of the port, so be sure to modify your software accordingly.

The software required to control the interface depends on the protocol used by your computer to send data to the parallel port. Many computers allow a POKE command to be executed in a BASIC program which places any number between 0 and 255 into the port's memory location. Table 2 lists the numbers which will activate the interface as described in figure 2. Using

this circuit in robotic applications involves programming the number commands into the port at specific intervals. Simple strings and delay loops within the software will do the job.

The possible uses of this interface are limited only by your imagination and the sophistication of your software. The circuit in figure 2 has been used to control a three-axis, open-loop robot arm that uses an electromagnet to pick up and move

Item	Quantity	Radio Shack #
2N2222 Transistor	8	276-1617 (pack of 15)
16-pin DIP, DPDT relay	1	275-215
16-pin DIP socket	1	276-1998
1N4000 series diode	1	276-1101
Electrolytic capacitor 4.7 mF, 35 WVDC	1	272-1012
44 pin plugboard	1	276-154
Terminal Strip	1	274-653

Table 1. Parts list for motor control circuit shown in figure 2.

Decimal	Hexa-decimal	Electro-Magnet	Motor 1	Motor 2	Motor 3
0	0	off	off	off	off
1	1	on	off	off	off
2	2	off	off	off	off
3	3	on	off	off	off
4	4	off	F	off	off
5	5	on	F	off	off
6	6	off	R	off	off
7	7	on	R	off	off
8	8	off	off	F	off
9	9	on	off	F	off
10	A	off	off	R	off
11	B	on	off	R	off
12	C	off	F	F	off
13	D	on	F	F	off
14	E	off	R	R	off
15	F	on	R	R	off
16	10	off	off	off	F
17	11	on	off	off	F
18	12	off	off	off	R
19	13	on	off	off	R
20	14	off	F	off	F
21	15	on	F	off	F
22	16	off	R	off	R
23	17	on	R	off	R
24	18	off	off	F	F
25	19	on	off	F	F
26	1A	off	off	R	R
27	1B	on	off	R	R
28	1C	off	F	F	F
29	1D	on	F	F	F
30	1E	off	R	R	R
31	1F	on	R	R	R

F = Forward

R = Reverse

Table 2. This list of numeric commands, when sent to the parallel port to which the control interface of figure 2 is attached, will operate the motors and electromagnet as shown. Note that the control circuit uses only five of the eight available bits from the parallel port.

small objects. All sorts of intriguing possibilities exist if you own a motorized Erector™ or Fischertechnik™ set.

If you want to get started in robotics, this interface will allow you to create your own experiments without breaking the bank.

Cautions

There are a few precautions about this design that should be mentioned. The devices being controlled depend on your computer's 5 V power supply to operate. Be sure that enough current is available for each device before you connect it to the interface. If necessary, avoid operating two devices simultaneously if their current requirements together will overtax your computer. When using motors, try to find the type with quiet brushes. Noisy motors will occasionally send a voltage spike through your computer system and interfere with its operation. If you use the interface to activate a relay to control 110 VAC house current, make sure that the control circuitry *never* comes in contact with the household current. For your safety, and the safety of your computer, this circuit should be used to control only low-voltage equipment.

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Editorial: *Continued from page 4*

microcomputer-controlled robot for experimentation. More importantly, the techniques used to construct and program Super Armatron can be applied to larger industrial robots."

Toys provide us with a method of experimenting with real-world concepts without having to worry about the expense of actual machines. If a part is damaged while experimenting with a toy, the toy can usually be replaced inexpensively. This is not necessarily the case if you need to replace a part on an industrial robot.

A design engineering friend of mine remarked that toys are learning tools, just like books. Books can describe how things work; they provide the mathematics, physics, and electronic principles behind the product's operation. Toys do not necessarily provide explanations; however, they do provide examples. By experimenting with toys, we can obtain a hands-on demonstration of what the books describe. This is the only way we can come to a full understanding of machinery and scientific principles.

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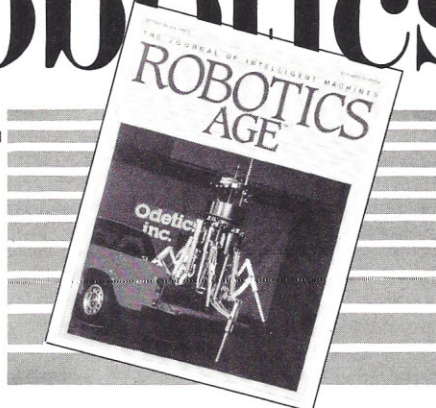
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In past issues, we've had several articles on walking robots—the design problems of legged mobility. One article described aspects of a one-legged hopping robot. Another described ODEX I, a recently designed experimental six-legged mobile robot. ODEX I has been widely publicized, including an appearance on a syndicated television series as well as



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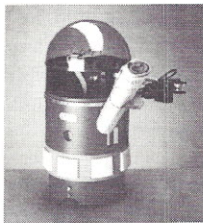
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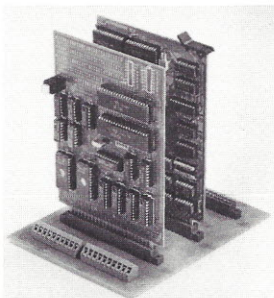
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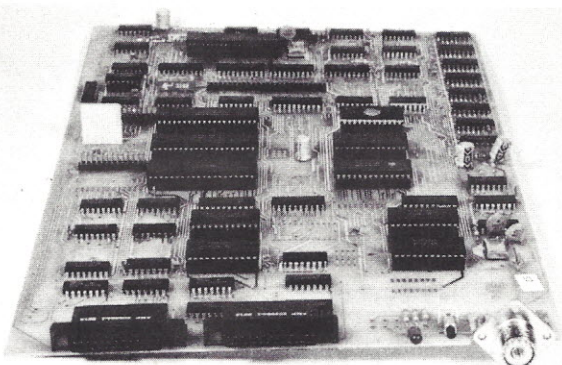
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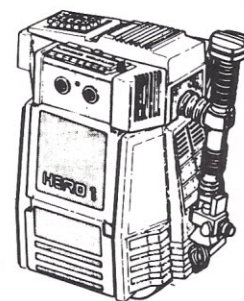
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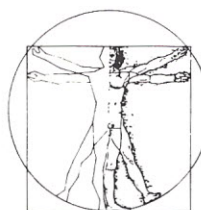
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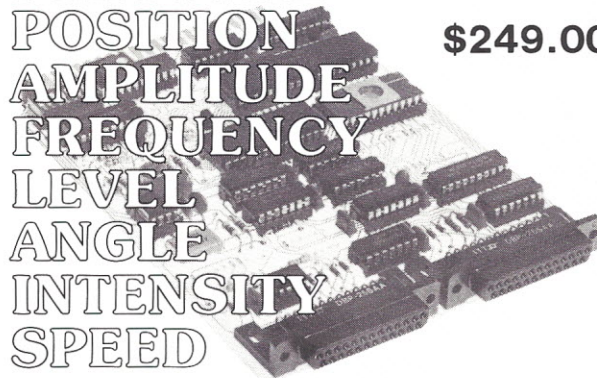
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New Products

Updated Logo from Terrapin

Terrapin, Inc.TM has announced Version 2.0 of its Logo for the Apple® II, II+, and ILe. Enhancements over the previous Version 1.3 include six new primitive functions and several new editor commands, improved garbage collection capabilities, full support for all four cursor keys on the Apple ILe, and the ability to read program files created under Apple Logo. These enhancements deliver several benefits. One of the new primitives, for example, allows easy switching between two disk drives. Text movement in the editor has been simplified through the use of the Yank com-

mand. The improved garbage collection virtually eliminates the problem of running out of workspace.

Terrapin has also released an enhanced version of their documentation which includes an extensive "Words and Lists" chapter. Terrapin describes their additional chapter as the most comprehensive treatment available of the Logo word and list handling features. Topics treated in depth in the new documentation subset include recursion, interactive graphics, quizzes, word games, and artificial intelligence programming.



For additional information contact: Terrapin, Inc., 380 Green St., Cambridge, MA 02139, telephone (617) 492-8816.

Circle 39

Plastic Cable Chain and Belt Manual

Winfred M. Berg, Inc. offers a 128-page pocket-size manual on its line of sprocket chains and drive belts for precision instrument and miniature power transmission applications. The polyurethane chains have stainless steel cable cores.

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feature excellent flexibility for twists and turns and a three-dimensional version enables power transmission at right angles.

Line drawings, specification tables, field splicing instructions, and a myriad of other design information is provided throughout the manual.

Copies may be obtained from Winfred M. Berg, Inc., 499 Ocean Ave., East Rockaway, NY 11518, telephone (516) 599-5010.

Circle 40

IBM Prototype Board

The Prototype Development Board (PD100) from Real Time Devices provides the means to quickly interface prototype circuitry to the IBM Personal Computer. A unique feature of the PD100 is a switch-selectable address decoder which frees the experimenter to concentrate on his design. Additionally, four I/O device-select signals, four power supply voltages, and a buffered data bus are available at wire-wrap posts. A rocker switch allows the selection of up to four unique addresses that do not contend with present IBM peripherals. This permits up to four boards to be utilized in one PC system.

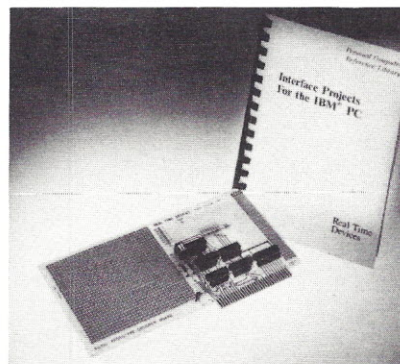
Two prototype areas are available; one is situated for installation of I/O connectors. These prototype areas are comprised of a grid of over 1600 pads on 0.1 in. centers suitable for soldering and installation of up to 40 wire-wrap sockets.

Provided with each PD100 board is a comprehensive 116-page documentation and projects manual. This manual is an invaluable aid to engineers, students, and ex-

perimenters. To those not familiar with interfacing with the IBM PC, this manual includes detailed circuits of I/O ports, A/D and D/A converters, transducers, and other useful interfaces along with BASIC application programs that illustrate control of the devices.

For more information, contact: Patricia Szybist, Sales Coordinator, Real Time Devices, PO Box 906, State College, PA 16801, telephone (814) 234-8087.

Circle 41



Natural Language for Microcomputers

Microrim, Inc. has introduced CLIOTM a conversational language inquiry option for their R:base Series 4000 data base management system. According to Wayne Erickson, Microrim president, "CLIO enables the user to query the data base in his own language, rather than computerese." CLIO allows users to build a dictionary of synonyms for words or operations associated with a data base. This process is set in motion when the user queries the computer with a word or series of words not already in the data base vocabulary. CLIO then responds with a series of questions to direct the user to define the unfamiliar term.

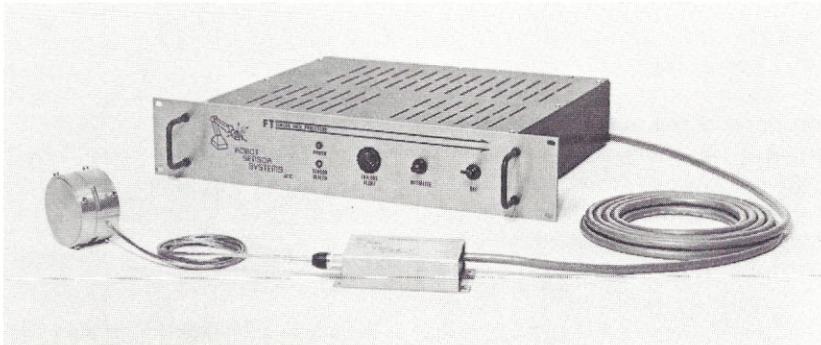
CLIO can also search through the data base to retrieve words based on adjectives or qualifying terms. The user could ask for "a list of the top three salesmen in orders for 1983," or "list all employees who have above average salaries" followed by "what are their birth dates?"

A special CLIO feature is the ability to simultaneously make inquiries into five different files from the 40 files available concurrently in R:base. CLIO will be available the first quarter of 1984 to accompany R:base, which requires 256 Kbytes of memory and operates on PC-DOS, MS-DOS, CTOS, BTOS, and UNIX. The interface will sell for less than \$200; R:base is priced at \$495.

For more information, contact: Microrim, Inc., 1750 112th Ave., N.E., Bellevue, WA 98004, (206) 453-6017.

Circle 42

New Products



Force/Torque Sensor System

The FT-15/50 Force/Torque Sensor System from Robot Sensor Systems, Inc. is a rugged, reliable force/torque sensing system for industrial robots. Basic components include a compact six-degree-of-freedom, solid-state piezoresistive force/torque transducer, a preprocessing electronics unit, up to 100 feet of connecting cable, and a high-speed microcomputer processing unit housed in a rack-mountable cabinet. Applications which have been successfully performed using force/torque feedback include threading, tightening, and removal of nuts and bolts; placing pins in holes; following contours; maintaining constant pressure under dynamic as well as static conditions; and mating and assembly of parts.

The FT-15/50 uses a compact piezoresis-

tive strain gauge. Forces and torques are measured to 15 lbs. (0.2 oz. resolution) and 50 in.-lbs. (0.4 in.-oz. resolution), respectively. Precision engineering and advanced design techniques make the FT-15/50 transducer the smallest in its class, yet it is overload-protected to five times its rated capacity.

The dedicated microcomputer processing unit automatically resolves the forces and torques applied to the transducer into six equivalent Cartesian force/torque components and transmits the results at up to 100 Hz rates. Raw transducer output is available at 500 Hz.

For more information, contact: Robot Sensor Systems, Inc., 10529 Freer St., Temple City, CA 91780, telephone (213) 444-4689.

Circle 43

Street Talk

Street Electronics' Echo™ speech products are available for Apple and IBM-PC computers. A general-purpose speech module controlled through an RS-232 port is also available. Each of the units uses a text-to-speech program which provides an unlimited vocabulary. The program contains an algorithm with over 400 language and pronunciation rules which convert written words into their corresponding phonemes. The Texas Instruments speech chip used with all Echo speech products uses the Linear Predictive Coding (LPC) method of speech generation. The user is provided with full control over phonemes, inflections, and volume. Modes are available for selecting speech word by word, letter by letter, or with all, most, or some punctuation spoken.

New with this series of Echo speech prod-



ucts is a dictionary of 700 natural sounding words spoken in a female voice. At present, Echo is one of the few speech synthesizers with this ability.

For more information, contact: Street Electronics Corporation, 1140 Mark Avenue, Carpinteria, CA 93013, telephone (815) 684-4593.

Circle 44



PC-Eye

A new IBM PC compatible video capture system, designed for diverse applications such as graphics/image processing, surveillance/security, quality assurance, motion analysis, machine vision, and training, is available from Chorus Data Systems, Inc. The PC-Eye™ Series 1000 board occupies one IBM PC or XT expansion slot. It permits the user to capture video images directly from inexpensive video cameras or recorders as rapidly as eight frames per second. The images may be digitized with one or two bits of intensity for compatibility with the IBM high-resolution graphics adapter, or digitized with four bits of intensity (640 by 400 pixel resolution) for display by other graphics adapter boards.

The digitized image is transferred under DMA control directly into the IBM PC main memory at up to 1 Mbyte per second. Successive frames may be captured and stored for off-line comparison or post-processing. Standard resolutions of 320 by 200 by 2 bits, 640 by 200 by 1 bit, and 640 by 400 by 4 bits have been selected to maintain compatibility with currently available graphics cards.

The high resolution and short image acquisition time provided by the PC-Eye converts the IBM-PC into a versatile, high-performance image processing system. Software support is offered for printer output, annotation, storage, comparison, compression, and transmission. The PC-Eye Series 1000 will be expanded with specific application software and hardware enhancements currently under development. Prices are less than \$500 in unit quantities.

For more information, contact: Chorus Data Systems, Inc., PO Box 810, Hollis, NH 03049, telephone (603) 465-2290.

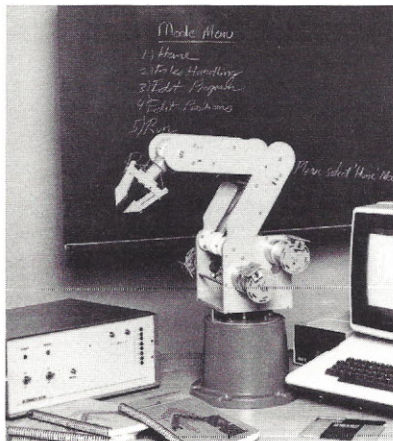
Circle 45

New Products

Scorbot Educational Robot

Eshed Robotec, Ltd. of Ramat Ilan, Israel, has developed an advanced educational robot, the Scorbot ER III, and a modular educational program of robotics instruction for technical high schools, higher institutes of learning, research laboratories, industry, and experimentalists. This unique system comprises the robot which can be operated from a host microcomputer, textbooks, laboratory exercises, advanced software and audiovisual aids such as videotapes and slides.

A major system component is the Scorbot ER III educational robot, designed and built in Israel. It provides ideal simulation using an "elite" language which closely approximates that of an industrial robot. The open arm construction allows users to observe the operational mechanism. DC servomotors with closed loop control are under



and eight outputs to allow for the robot to the control of an 8-axis controller which is capable of simultaneous control on all eight axes.

The controller has provisions for a plug-in teaching pendant and also eight inputs

react and interact with its environment. This facilitates the simulation of real live robotic applications in the classroom, using conveyors, indexing carousels, etc.

An RS-232C serial interface allows for communications with a host microcomputer. Control software is available for a number of microcomputers. The modular format of the robotics instruction program comprising video tapes, slides, overhead transparencies, and written texts, which include theory and practical laboratory experiments as well as sophisticated software.

The complete Scorbot package will enable any user to gain a fundamental hands-on understanding of both the concepts and uses of robots in our modern world.

For more information, contact: Noam Kra-Oz, Eshed Robotec, Ltd., PO Box 28346, Tel Aviv 61 282, ISRAEL, telephone (03) 340860, telex: 361131 ESHED IL.

Circle 46



Turtle Tots

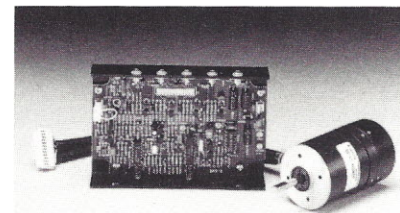
The inexpensive Turtle Tot is manufactured in Australia and distributed in America by Harvard Associates, Inc. According to president Andre Rossi, "We think the idea of a truly personal, yet very affordable, Turtle robot has now become a reality with Tot. With a retail price of \$299, Turtle Tot is already selling at an unprecedented rate."

The Turtle Tot is controlled via an RS-232 serial interface and requires an external

computer. The Tot can move, draw, turn, blink its eyes, and feel its surroundings with touch sensors. An optional speech package allows the Tot to talk. All Turtle Tots come fully assembled and tested, with easy-to-read instructions and a ten-color pen set.

For more information, contact: Harvard Associates, Inc., 260 Beacon St., Somerville, MA 02143, telephone (617) 492-0660.

Circle 47



Brushless DC Motor With Built-In Encoder

Accurate speed control, low electrical and mechanical noise, high reliability and long life make the Model BZ-52 brushless DC motor ideal for use in applications such as laser beam printers, computer peripherals, business machines, and medical equipment.

The rated voltage is 24 V, rated speed is 4000 rpm, rated torque 60 g-cm, and rated current 600 mA. The starting torque is 300 g-cm. The speed stability of ± 0.01 percent with a maximum jitter of 0.03 percent is achieved by means of a photoencoder. The motor diameter is 52 mm, the length is 84 mm. The electronics drive circuitry is included.

For more information, contact: Canon USA, Inc., Electronic Components Division, One Canon Plaza, Lake Success, NY 11042.

Circle 48

New Products



Complete Robot Teaching System

Lennox Education Products has introduced a robotics training package priced at \$2,700. Called the Lennox Teaching Robot, this package is designed for use in educating and training robotic application technicians. The Lennox Teaching Robot utilizes an industrial training format to teach students to select and program robots. This package can also be used for instruction in maintaining and troubleshooting robotic applications. This robot is part of a complete training system with individual components which can be tailored to spe-

cific robotic teaching needs.

Each Lennox Teaching Robot includes a single, arm pick-and-place pneumatic manipulator, a valve interface, a Timex/Sinclair 1000 computer and printer, a control panel, a television receiver, and a cassette recorder. The computer, panel, and television are used to establish the robot's programs and the cassette recorder is used to store them.

For more information, contact: Robert Hamos, Manager of Lennox Education Products, PO Box 809000, Dallas, TX 75380, telephone (214) 233-9407. Circle 49

Visual Patterns

Pattern Processing Corp. has started shipping their APPTM 100 Associative Pattern Processor. This machine vision recognition system is the first in a series of products that performs pattern identification by hardware circuitry extensions beyond traditional programming. The APP 100 and APP 200 systems provide fast, accurate, quality vision recognition with the use of complicated computer software. The APP system has a 3,000 part-per-minute image recognition capability using a pixel density of 154,880 per image processed. The image density is 320 pixels by 484 pixels, each with 64 levels of gray.

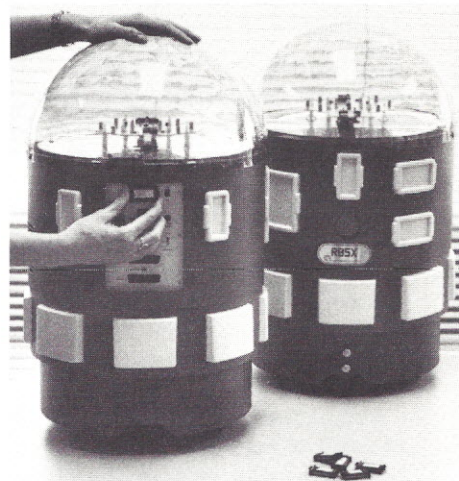
The system can adjust to nonuniform lighting and has no shape restrictions regarding images. The system operation features continuous image recognition, an adjustable sensitivity from 0 to 100 percent, and the ability to freeze-frame an image without stopping the processing. The system can store up to 255 images (each image having a multitude of configurations) in the



main processor. The APP 200 version can provide 256 independent windows on any single image. Expansion of up to 510 independent images is already planned.

For more information about the Associative Pattern Processor, contact: JoAnne Anderson, Pattern Processing Corp., 511 Eleventh Avenue South, Minneapolis, MN 55415, telephone (612) 339-8488.

Circle 50



RB5X Software Modules

RB Robot Corporation has released four preprogrammed software modules for the RB5X Intelligent RobotTM. These modules enable the RB5X to perform specific tasks as soon as the robot is turned on.

Pattern Programmer allows you to press combinations of the robot's tactile sensors, or bumpers, to instruct RB5X to follow a specified pattern. **Bumper Music** allows the bumpers to be played like keys on a piano. Tunes can be recorded and played back. **Spin the Robot** contains a game routine that allows children to interact with an RB5X equipped with voice/sound synthesis. The **Intruder Alarm** and **Daisy, Daisy** software module contains a routine which allows the robot to sense movement with its sonar and sound an alarm. **Daisy, Daisy** enables the RB5X to sing the song made famous by HAL in the film, "2001: A Space Odyssey."

An arm training software module is also available which allows you to teach the RB5X arm to perform certain specific movements. The RB5X is also delivered with a utility software module that contains a self-diagnostic program. This routine checks the robot's batteries and motor functions.

RB5X feels the availability of off-the-shelf application software for personal robots should provide a significant boost to the personal robot industry in 1984.

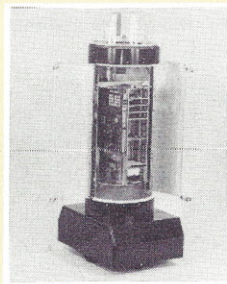
For further information, contact: Sharon D. Smith, RB Robot Corporation, 18301 West 10th Avenue, Suite 310, Golden, CO 80401, telephone (303) 279-5525.

Circle 56

1984 ROBOTICS AGE PRODUCT GUIDE

Robotics Age Product Guide:

A Sourcebook for
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